METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 54 No. 325 NOVEMBER, 1956 Monthly: TWO SHILLINGS

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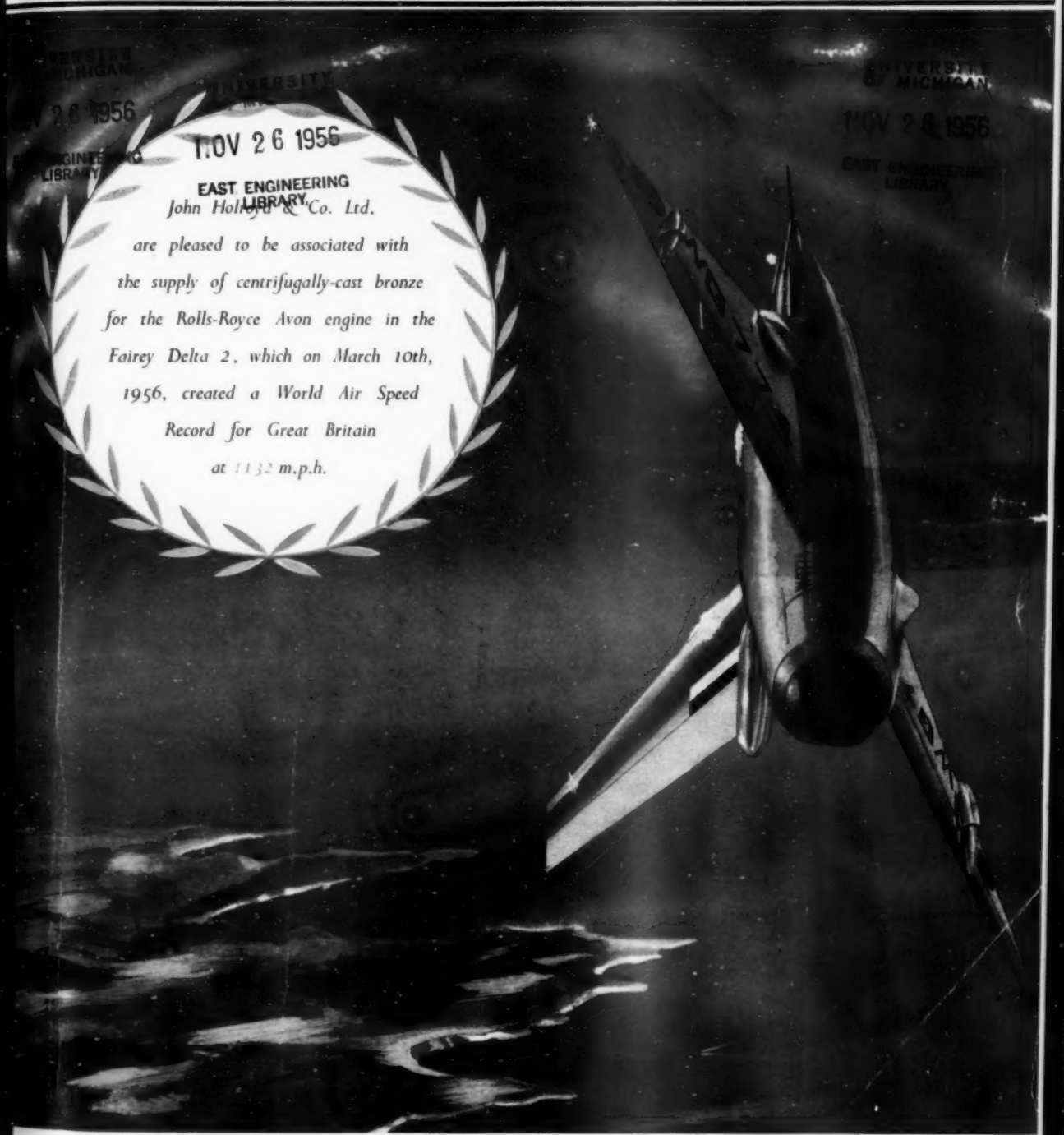

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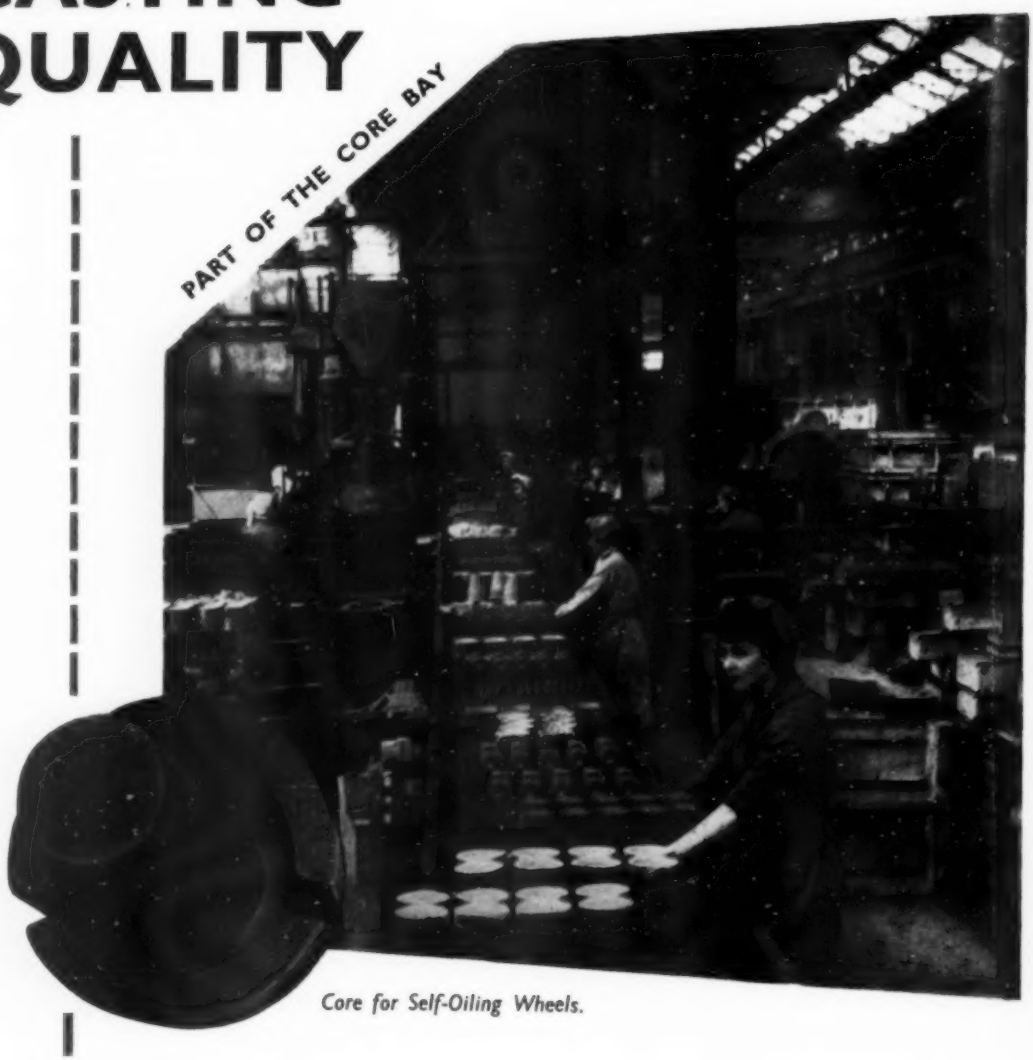

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THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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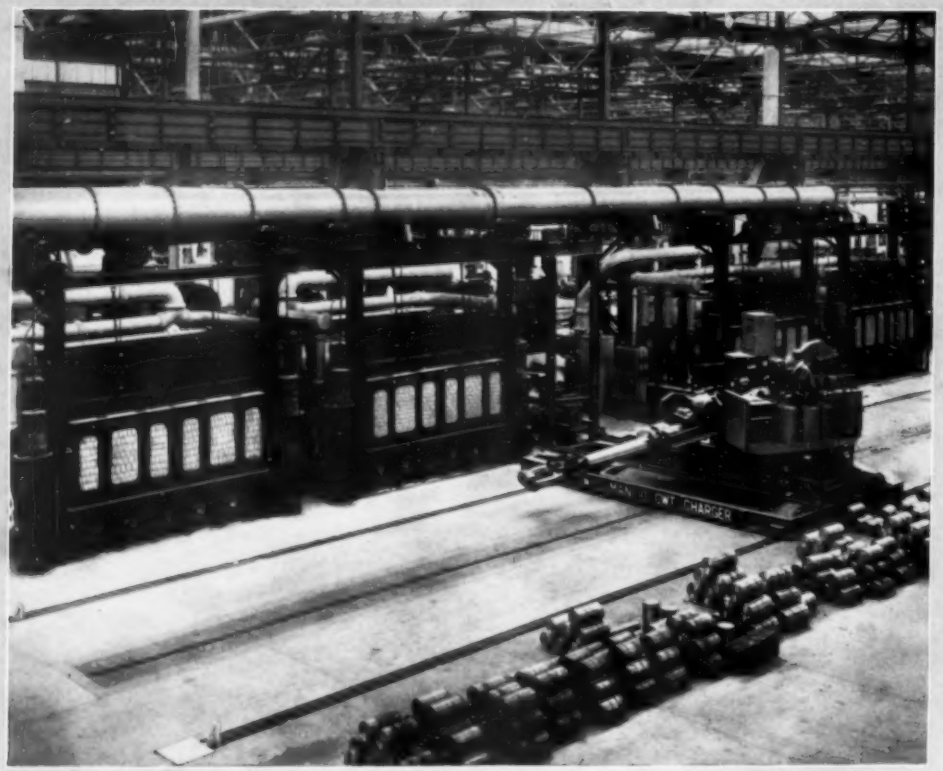

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THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

NOVEMBER, 1956 Vol. LIV. No. 325

The Atom Age

ON August 6th, 1945, the word "atom" took on a new and terrifying significance, for on that day the Japanese city of Hiroshima was devastated by the explosion of a single bomb, whose destructive power made the 10-ton blockbusters which had rained on Germany seem like penny fireworks. Hitherto, "atom" had signified something very small, and the concept of enormous power locked-up in such tiny particles of matter was one which existed only in the minds of a small number of scientists and a few "outsiders" in Government circles who were aware that work was in progress on the development of the bomb. During the 11 years that have since elapsed, weapons of ever-increasing power have been exploded in tests carried out in several countries, first, like the Hiroshima bomb, based on the principle of nuclear fission, and later thermo-nuclear devices of the hydrogen bomb type. Whether such terrible weapons will ever be exploded in anger, as a means of spreading death and destruction, or whether their very existence will act as a deterrent and so prevent another world war is a question to which time alone holds the answer.

In the end it may all be working to the common good of mankind, but in the meantime the publicity given to the destructive power of these new weapons, and to the possible harmful genetic effects of the increasing general radioactivity resulting from test explosions, has led many people to feel that it would have been better if scientists had never discovered the secrets of the atom. Just as in the case of aerial warfare, when the responsibility for its introduction was laid at the door of those who had developed the aeroplane, the scientist and technologist are made the scapegoats. Science is a seeking after the fundamental truths of nature, and the fact that in his search the scientist discovers a principle on which can be based the development of an engine of destruction is not a valid reason for discontinuing the search. The truths are there to be discovered: what use is made of them subsequently is not just the concern of the scientist, although he must share with the rest of humanity the responsibility for the moral development of mankind to the stage where the use of atomic weapons, or any other weapons for that matter, would never even be considered.

But not all progress in the atomic field during the last decade has been concerned with weapons. Whilst there is yet no generally available evidence that thermo-nuclear reactions of the type used in the hydrogen bomb can be controlled, it is possible for nuclear fission to take place in such a way that the reactions can be harnessed to the production of power in the form of electrical energy. The energy in fission is imparted in the first place to the two fragments into which the atomic nucleus is split, causing them to move apart with great speed. No way of using the energy of these fragments directly has yet been devised, but their motion through the uranium heats the metal, and this heat can be removed and converted into mechanical energy by a steam engine or gas turbine. The two principal items of an atomic power station, therefore, are a reactor in which fission takes place and heat is produced, and a prime mover coupled to an electrical generator. There are many ways in which the heat can be generated in the reactor and transferred to the prime mover, and several schemes are at present under investigation in this country and abroad. In the meantime Britain has gone ahead with the building of Calder Hall, an atomic power station capable of supplying electrical energy on an industrial scale. When Her Majesty The Queen, on October 17th, moved the switch that enabled power to be fed to the grid, it marked the beginning of a new age, for, although an experimental station has been in operation in Russia since 1955, to Calder Hall belongs the distinction of being the first place at which electricity has been produced on a large scale from atomic fuel.

We are not, on the whole, regarded as a nation of hustlers, but the designing and building of such a revolutionary development as a nuclear power station in three and a half years could be considered fast work by any standards. When work began, several major parts of the design had only roughly been worked out, and contractors had no tangible example to guide them—the station was to be the first of its kind. It can fairly be claimed that Calder Hall is among the finest achievements of British heavy engineering, but why the hurry? Would it not have been better to delay the building of atomic power stations until such time as the most economic type for our purpose could be established? The simple answer is that we have been forced by sheer economic necessity, because the demands for power are outstripping the availability of coal. The alternatives are oil and atomic energy. Oil could supply the answer at the moment, although it is more expensive than coal for steam raising. There are also the serious political and technical difficulties of getting it to this country from the Middle East, or elsewhere, and the uncertainty as to how long the world supply of oil will last at ever increasing rates of consumption.

The shortcomings of conventional sources of power will doubtless stimulate the same kind of development in other countries in a few years time. In addition there opens up the possibility of setting up power plants in places previously ruled out because of the cost of transporting fuel, and it was, no doubt, with this in mind that Her Majesty said: "Above all we have something new to offer to the people of the underdeveloped and less fortunate areas of the world, who will continue to look to us for assistance and example as they have done in the past. This to me is the real importance of to-day's ceremony. It may well prove to have been among the greatest of our contributions to human welfare that we led the way in demonstrating the peaceful uses of this new source of power."

Meeting Diary

1st November

Institute of British Foundrymen, Stoke Section. "Core Assembly Methods," by E. H. Beech. Stipendiary Court Room, Hanley. 7.30 p.m.

Institute of Metals, London Local Section. "Primitive Metallurgy," by Professor F. C. Thompson. Royal School of Mines, South Kensington, London, S.W.7. 7 p.m.

Institution of Production Engineers, Reading Sect'on. "Heat Treatment and Furnace Brazing," by J. B. Carroll. The Canteen, Transport Equipment (Thornycroft), Ltd., Basingstoke. 7.30 p.m.

Leeds Metallurgical Society. "Powder Metallurgy Applied to Mechanical Parts," by H. Davies. Large Chemistry Lecture Theatre, The University, Leeds, 2. 7.15 p.m.

5th November

Institute of British Foundrymen, Lancashire Branch. "Fast Drying Bonding Materials," by A. I. Donaldson. Midland Hotel, Manchester. 7 p.m.

Institute of British Foundrymen, Sheffield Branch. "Training," by O. W. Reynolds, and "Foundry Training," by H. Parkin. Sheffield College of Commerce and Technology, Department of Engineering, Pond Street, Sheffield, 1. 7 p.m.

6th November

East Midlands Metallurgical Society. "Physical Requirements in Steel Castings," by W. J. Jackson. Nottingham and District Technical College. 7.30 p.m.

Incorporated Plant Engineers, London Branch. "The Use of Radio Isotopes in Industry," by C. W. Jones. Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2. 7 p.m.

Institute of British Foundrymen, Slough Section. "Gases in Metals," by Dr. C. E. Ransley. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Institute of Metals, Oxford Local Section. "Radiation Damage," by Dr. A. T. Churchman. Cadena Cafe, Cornmarket Street, Oxford. 7. p.m.

7th November

Institute of Production Engineers, Nottingham Section. "Spring Design and Manufacture," by J. A. Roberts. (Illustrated by slides). The Victoria Station Hotel, Milton Street, Nottingham. 7 p.m.

Institution of Production Engineers, South Essex Section. "New Metals—with Specific Reference to Titanium Zirconium, Molybdenum, etc.," by Dr. T. W. Farthing. The Ilford Club, 21a, Balfour Road, Ilford. 7.30 p.m.

Institute of Welding, Manchester Branch. "Pressure Welding," by R. F. Tylecote. Reynolds Hall, College of Technology, Manchester. 7.15 p.m.

Manchester Metallurgical Society. "The Properties of Hiduminium 100 (S.A.P.)," by Dr. W. M. Doyle. Manchester Room of the Central Library, Manchester. 6.30 p.m.

8th November

Institute of British Foundrymen, Beds. and Herts. Section. "Mechanising a Small Jobbing Foundry," by R. H. Blandy. Small Assembly Room, Town Hall, Luton. 7.30 p.m.

Institute of Metals, Birmingham Local Section. "The Metallurgy of Steel for Deep Drawing and Pressing," by A. J. K. Honeyman. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham. 6.30 p.m.

9th November

Institution of Production Engineers, Gloucester Section. "Some Aspects of Protection Processes," by R. Gillanders. The Technical College, Brunswick Road, Gloucester. 7.30 p.m.

10th November

Institute of British Foundrymen, Scottish Branch. "The CO_2 Process—A Recap," by R. Spencer. Royal Technical College, Glasgow, C.1. 3 p.m.

13th November

Institute of Metals, South Wales Local Section. "Fuel," by C. A. J. Plummer. Electricity Showrooms, Kingsway, Swansea. 6.45 p.m.

13th November

Institution of Production Engineers, Birmingham Graduate Section. "Pattern Making," by a representative of Wright and Platt, Ltd. The James Watt Memorial Institute, Great Charles Street, Birmingham. 7 p.m.

Institution of Production Engineers, Halifax Graduate Section. "Die Casting—The Production of Certified Zinc Alloy Die Castings," by R. Parish. The Huddersfield Technical College, Huddersfield. 7.30 p.m.

15th November

Institution of Production Engineers, Glasgow Section. "Electric-Spark Machining," by G. Fefer. Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2. 7.30 p.m.

Liverpool Metallurgical Society. "Some Metallurgical Aspects of Welding Non-Ferrous Metals," by P. T. Houldcroft. Joint Meeting with the Liverpool Branch of the Institute of Welding. Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool. 7 p.m.

16th November

Institution of Mechanical Engineers. "Simulated Gear Tooth Contacts—Some Experiments Upon their Lubrication and Subsurface Deformations," by Dr. A. W. Crook. 1, Birdcage Walk, Westminster, London, S.W.1. 6 p.m.

17th November

Institute of British Foundrymen, Bristol and West of England Branch. "Some Aspects of Modern Casting Design and Running Technique," by R. W. Ruddle. Grand Hotel, Broad Street, Bristol, 1. 3 p.m.

19th November

Institute of Metals, Sheffield Local Section. "Automation," by Dr. H. D. Turner. Engineering Lecture Theatre, The University, St. George's Square, Sheffield, 1. 7.30 p.m.

Institution of Production Engineers, North Eastern Section. "The Manufacture and Some Applications of Seamless Metallic Tubes," by C. Cashmore. The Neville Hall, Newcastle on Tyne. 7 p.m.

Institution of Production Engineers, Sheffield Graduate Section. "Corrosion Prevention," by M. Lewis. Gummers, Ltd., Rotherham. 6.30 p.m.

North East Metallurgical Society. "Analytical Control by the Quantometer," by W. S. Sykes. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

20th November

Institute of British Foundrymen, East Anglian Section. "Some Modern Methods of Patternmaking with particular reference to Pressure Cast Pattern Plates," by B. N. S. Perry. Lecture Hall, Public Library (Old Foundry Road Entrance), Ipswich. 7.30 p.m.

Institution of Production Engineers, Halifax Section. "Recent Developments in High Production Foundries," by J. D. Berry. The George Hotel, Huddersfield. 7.15 p.m.

Institution of Production Engineers, London Graduate Section. "Induction, Resistance and Electro-Gas Heating for Soldering and Brazing," by C. Eadon-Clarke. Institution of Production Engineers, 10, Chesterfield Street, London, W.1. 7.15 p.m.

21st November

Institute of British Foundrymen, London Branch. "Symposium on Dust, Fume, Heat and Noise Suppression." (a) "Cupola Furnaces," by M. M. Hallett; (b) Electric-arc Steel Furnaces," by J. Bain; (c) "Crucible Furnaces," by D. W. Brown. Constitutional Club, Northumberland Avenue (south-east from Trafalgar Square), London, W.C.2. 7.30 p.m.

Institute of British Foundrymen, Southampton Section. "Shell Moulding," followed by film. Technical College, St. Mary Street, Southampton. 7.30 p.m.

Institution of Production Engineers, Derby Section. "Drop Forgings in Alloy Steels," by E. H. Henderson. (Illustrated by a film). The Irongates Hotel, Irongate, Derby. 7 p.m.

Manchester Metallurgical Society. "The Role of Grain Boundaries in Creep," by Dr. D. McLean. Manchester Room of the Central Library, Manchester. 6.30 p.m.

(Continued on page 222)

The Industrial Application of Television

Remote Observation Facilitated by Closed Circuit Equipment

Although the industrial application of television made a rather slow start, increasing use is being made of closed-circuit equipment to meet a number of industrial needs. Following a brief discussion of the requirements of such equipment, reference is made to a number of typical applications.

TELEVISION as an entertainment medium has been with us for nearly two decades and is now accepted as part of our everyday lives. In view of the vast amount of research and ingenuity that have been devoted to its perfection, it is rather surprising that its great potentialities as a more direct servant of humanity have not so far been more fully exploited. Instead of harnessing this willing slave, we have almost allowed it to enslave us.

In every aspect of modern life the need for efficient and rapid means of communication is evident. As such, television has a number of attributes which, when taken together, are almost unique. It is difficult to think of any other system which combines, as television does, the advantages of pictorial representation, instantaneous transmission, no limit to the number of observers or reception points, and the inherent assurance that the information received is correct. There are, of course, limitations to its usefulness. Many of these are, however, of a purely practical nature and will be progressively overcome in the future.

Requirements of Industrial Television System

It is not difficult, from practical considerations, to make a list of requirements for a television system suitable for industrial use. It must be :—

(1) Reliable and rugged.

(2) Simple to operate.

(3) Compact and light (particularly the camera).

(4) Economical to instal and to maintain.

(5) Flexible.

It is also desirable that complete control of the camera should be possible from the viewing position. These requirements immediately lead to the following :—

(1) The circuit should be as simple as possible, compatible with adequate performance, to minimize the number of components.

(2) Controls should be as few as possible, and the need for continuous adjustment must be eliminated.

(3) All operational controls and the majority of components should be located in a unit separate from the camera.

(4) The pick-up device should be small, reliable and cheap. The cost will, of course, be related to the life of the tube.

From these requirements we can now consider in more detail the design of a typical system (Fig. 1).

The electronic pick-up tube is the nucleus of the equipment, and the type employed will largely determine the suitability of the equipment for any particular application. Generally speaking, in broadcast television, the prime requirements of the pick-up tube are sensitivity, resolution and good tonal reproduction. The cost of the tube, its size, and the problems involved in its use are of secondary importance. Thus, the Image Orthicon, probably the most commonly used pick-up tube in broadcast television today, whilst giving pictures of superb quality without the necessity of special illumination of the subject, needs complex circuitry for its operation, is of considerable size, retains semi-permanently images which are allowed to remain stationary for more than about 30 seconds, and costs upwards of £1 an hour to operate. Clearly, such a tube would not be suitable for all but the most specialised industrial applications, and some alternative was therefore required.

If a luminous image is focussed on to the target, the conductivity of illuminated portions of a Vidicon tube will be increased in proportion to the amount of incident

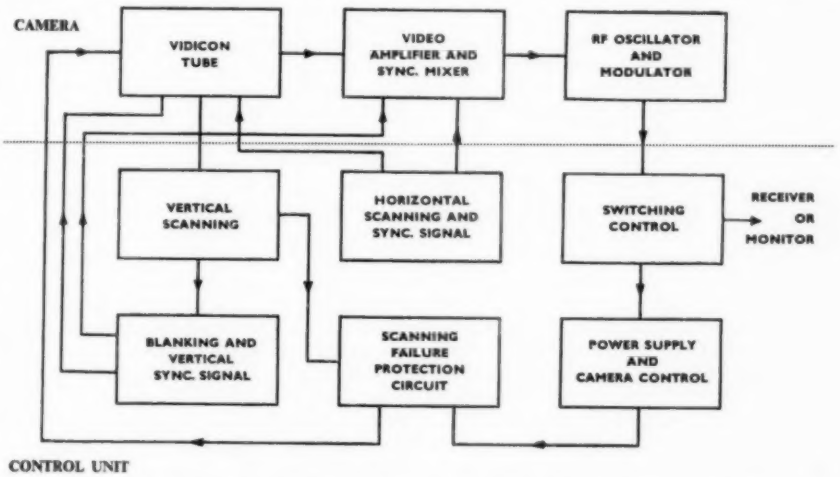


Fig. 1.—Circuit arrangement of closed-circuit television equipment.

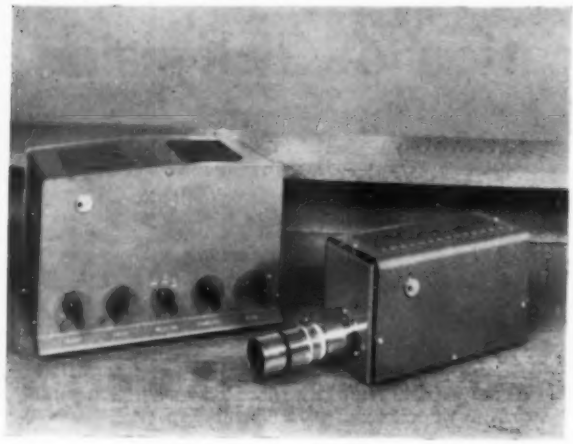


Fig. 2.—Marconi camera and control unit.

light at any given point. It is the resultant voltage fluctuation which constitutes the output "video" signal from the tube. This signal must be amplified to a suitable sending level, and must be provided with a set of synchronising pulses. It is, therefore, necessary that the camera should contain, in addition to the pick-up tube and its scanning yoke, a video amplifier and a mixer valve. The power supplies and the scanning circuits can be contained in a separate control unit, which can also contain the controls for the Vidicon. These two units are connected by a multi-core cable which, for practical reasons, is usually limited to around 500 ft. in length.

The Marconi industrial television camera and control unit are shown in Fig. 2. The simplest type of scanning circuitry is used, and the complete equipment contains only ten valves plus a metal rectifier and the pick-up tube. There are six pre-set controls on the back of the control unit, four operational controls on the front, and an on-off switch. The camera contains only three valves in addition to the pick-up tube and one pre-set control. Its physical dimensions are $4\frac{1}{2} \times 5\frac{1}{4} \times 8\frac{1}{2}$ in., and it weighs only $4\frac{1}{2}$ lb.

This equipment operates on the C.C.I.R. television system, 625 lines, 50 fields, negative modulation. This system gives a better vertical resolution than the British 405-line system, and is also compatible with the American 525-line 60-fields system, so that the equipment will operate on either system without adjustment according to the mains frequency. The advantages of this from the price point of view should be obvious. Furthermore, export receivers, which are easily obtainable in this country, are not subject to purchase tax.

For use with this equipment has been designed a special monitor with a 14 in. screen, which is housed in a compact steel case and is rather more suitable than a domestic receiver in some types of installation. To complete the equipment, various accessories have been designed, and many more will undoubtedly be added as the need arises. Remote control of the optical focus at the camera can be provided, for example, by a small unit which is bolted to the front of the camera, and which contains a motor to drive the lens in and out. Remote orientation of the camera in the vertical and lateral directions can also be provided. Various types of camera case and camera mounting are also available.

Stereoscopic viewing is occasionally required, and this can be achieved in one or two ways. Perhaps the biggest lack at present is colour; although colour television is possible, the enormous increase in complexity and, therefore, cost of the equipment normally precludes it on economic grounds in many countries.

The foregoing indicates the problems involved and the method by which they have been solved by one manufacturer. There are, of course, many other types of industrial television equipment now in existence. Most available equipments now employ the Vidicon type tube, and the techniques used are generally similar to the above.

Applications

Generally speaking, applications for any system of remote observation can be divided into the following categories:

(1) Where direct observation could be dangerous to the observer.

(2) Where direct observation involves moderate or acute discomfort to the observer.

(3) Where simultaneous or sequential observation of several phenomena at widely spread points is required.

(4) Where observation is required at a distance from a given phenomenon, or at a point from which direct observation is impossible.

(5) Where simultaneous observation is required by a large group of observers.

(6) Where direct observation from any accessible position is physically impossible.

The applications to be reviewed are, therefore, divided into the above categories, and it is hoped to indicate in each case why television is the obvious choice.

Direct Observation Dangerous

The first category, where direct observations would be dangerous, includes several obvious applications. The observation of destruction tests, for example, is frequently a hazardous business, and close observation is normally impossible. A television camera, however, can easily be protected and, by a suitable choice of lens, as close a view as is desired can be obtained. Large structures, high voltage insulators, and high speed mechanisms can be viewed in this way, and it is interesting to note that the equipment will give very satisfactory pictures in conjunction with stroboscopic illumination. A graphic example was recently cited from Italy, where the installation of television in a nitroglycerine factory gave sufficient warning of an impending explosion for the whole works to be evacuated in time.

There are many applications in the atomic energy industry. Cameras are being successfully used for the interior inspection of the atomic piles at Windscale during maintenance shut-down periods, a procedure which cannot be carried out in any other way. The camera is mounted on a simple pan and tilt head on the end of an aluminium scaffold pole, wrapped in polythene sheet as a protection against radioactive dust, and is inserted into the pile through one of the loading holes in the biological shield. Lighting is inserted on similar poles, through adjacent holes. The camera can be directed as desired, once inside the pile, by steel wires operating the pan and tilt head, and a very satisfactory view of any desired part of the structure is obtained.

Direct Observation Uncomfortable

The second category involves applications which would cause moderate or acute discomfort to the observer. The observation of gas-turbine and rocket motors under test, for example, which also frequently involves considerable hazard, can be very well achieved by means of television.

The viewing of flame conditions in large furnaces is another example. Direct viewing through smoked glass is common practice, but subjects the observer to the hazard of being simultaneously blinded and roasted. Furthermore, it is normally necessary for the furnace operator to leave his control position to do this. The advantages of a television display at the control position need not be emphasised. Messrs. Marconi, Ltd., have carried out a considerable number of tests on boiler furnaces with the co-operation of the Central Electricity Authority.

For use in studying flame conditions in a power-station furnace, the camera is mounted on a bracket and protected from the intense radiant heat by a double water-cooled window. Air is blown across the front face of the window to sweep it clean of ash, and also blows back through two tubes on to the sides of the camera for cooling purposes. The camera bracket is hinged to permit rapid removal of the camera in case of water or air failure. Apart from the absence of colour, the television picture shows as much detail as one can see by direct observation.

An alternative system involving a periscope has been successfully used on both power-station and open-hearth furnaces. The periscope used was designed by Mr. Charles Burns of B.I.S.R.A., and has the advantages that the camera is well away from the heat of the furnace, and that any part of the interior of the furnace can be viewed by suitable orientation of the periscope, which contains a pivoted mirror and can be rotated about its own axis. The periscope is water-cooled and an air-blast is provided to clean the viewing ports.

This system is particularly useful on furnaces to which access is limited, such as the modern type of pressurised power-station furnace having very small viewing ports. One firm of boiler makers is now using this equipment in the commissioning of new boilers, and the C.E.A. is about to make the first permanent flame-viewing television installation in the United Kingdom at Willington "A" power station (Fig. 3).

A further example in this category is the observation of steel-pouring and continuous processes in general, eliminating the need for a local observer, and also, of course, the possibility of mis-interpretation of arm signals.

Simultaneous Observation at Several Points

The third category involves applications where simultaneous or sequential observation is required of several phenomena at widely spread points. There is normally no other means of achieving this without multiplicity of personnel, and television can therefore effect a very real economy and increase of efficiency.

The observation of several parts of a large machine, such as a paper-making machine or a printing press, is an example. One plastics manufacturer is contemplating the installation of this equipment as a means of preventing damage to the callenders of a plastic rolling machine due to loss of feed. Critical points on long conveyor belts can be watched from any desired position, and

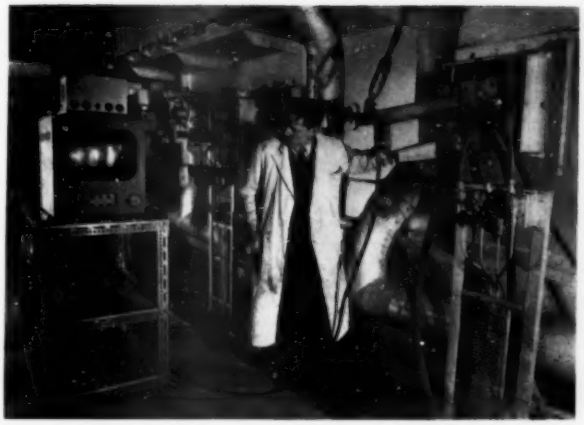


Fig. 3.—Camera used in commissioning and servicing of steam boilers in power stations.

there are many such applications in large airports and on the railways.

A motor-car manufacturer plans to instal television to control the flow of delivery lorries from the reception parks to the goods-inwards entrance, to which access is restricted and from which the reception parks cannot be seen. Plant security and supervision of entrances could similarly be controlled by one man from a central office by the installation of television cameras. In this connection, it might be mentioned that virtually any number of cameras can be connected by a switching system to one viewing monitor if required.

Observation at a Distance

In the fourth category, where observation is required at a distance from a given phenomenon, or at a point from which direct observation is impossible, there are many examples. Television is becoming a standard technique for the remote observation of water-level gauges on large boilers which may be up to 150 ft. above the level of the boiler control panel. Periscopes are extensively used for this, but can only provide a very small image of the gauge, due to the distance involved, and, for geographical reasons, cannot normally bring the image to the control panel. Other systems exist, but none possess the inherent inability of television to give a false reading—if the picture is there it must be right. Telemetering in general can be very satisfactorily achieved in this way, and the television system can often enable the duplication of expensive equipment to be avoided.

There are a number of applications in the steel and iron industry. Some interesting tests have been made on slab re-heat furnaces and, with suitably placed cameras to give the operator a view through the furnace, and of the entrance and exit, have shown that a number of furnaces can be operated by one man, and that slab misalignment and other causes of blockages can be avoided.

The first television installation in a steelworks in this country will be made shortly to assist the control of a hot-strip run-out table. As a slab progresses through the rolling process, uneven screw-down pressure may cause the strip to camber, thus resulting in a waste of time and material due to uneven coils. The television camera, mounted above the coiler guides, will transmit a picture to the control position and allow the operator to make

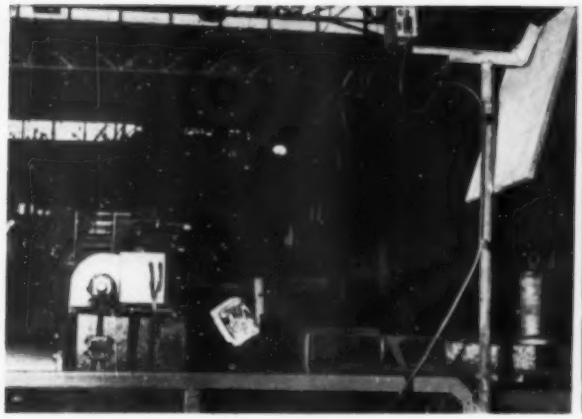


Fig. 4.—Camera mounted in position to enable mill operator to watch ingot movement.

Fig. 5.—Mill operator watching ingot movement on monitor to left of large dial.

the necessary adjustments to his screw-down control to correct for misalignment. In a similar way, suitably placed cameras would allow the operator to detect conditions which would lead to cobbling of the strip, a serious occurrence which requires the immediate stoppage of the process.

Marconi Industrial T.V. equipment was rushed into action at the Abbey Works of the Steel Company of Wales, when the failure of a slab manipulator put the slabbing mill out of service. By providing an "eye" on the far side of the mill (Fig. 4), the T.V. equipment once more enabled the operator to control the movements of the ingots through the rolls with precision. The mill was thus brought back into full service with an output of 1,600 tons per shift being maintained on a three-shift round-the-clock basis. Fig. 5 (unretouched) shows an operator at the control position of the slab rolling mill, with the monitor screen to the left of the main dial: a picture of an ingot can be clearly seen on the screen.

A further interesting example in this category is the use of television equipment to assist optical jig-setting or lofting. The camera is used in conjunction with the normal transit telescope, and the image is produced, much enlarged, on the receiver screen. Not only can jig-setting or lofting be carried out in this way by one man, but accuracy is considerably increased and eye-fatigue in the observer is eliminated.

Using this equipment, documentary information can be rapidly transmitted from one point to another over considerable distances. There are a host of such applications in factories—for example drawings may be transmitted between offices or buildings quite satisfactorily in this way.

Simultaneous Observation by Several Persons

The fifth category covers applications where simultaneous observation is required by a large group of observers. One manufacturer used television as a means of overcoming the lack of wiring models for an electronic chassis of which a batch were required quickly. A receiver was placed in front of each wireman, who followed the operations of an instructor wiring up a model being observed by the television camera.

Direct Observation Impossible

Finally, there are the applications where direct observation is physically impossible from any accessible position. Interior inspection of long pipes or narrow vessels could well be achieved by means of television. There are a number of applications in this category in the aircraft industry, where the equipment permits the observation of various aircraft parts during flight, the observation of icing conditions on aircraft surfaces during flight, and so on.

There is every possibility of the production of an infra-red sensitive pick-up tube in the future, and this will, of course, open up a whole new field of applications where observation is at present impossible.

Operational Considerations

The above examples, which are necessarily somewhat random, should indicate the tremendous potentialities of television as an industrial tool. It should be emphasised that the equipment now available is not of great complexity, and its maintenance and operation should not constitute any great problem now that electronics in general is being used more and more extensively throughout industry.

To achieve the best results from the equipment, proper attention should be given to good engineering practice, particularly in regard to heat, contaminated atmospheres and liability to mechanical damage. It is normally advisable to consult a specialist firm when details of a particular installation are to be determined, and most companies are now in a position to offer satisfactory after-sales service.

Conclusion

With the development of automation in the future, and with the generally increasing need for rapid methods of communication, television will become an established technique for an increasingly wide range of applications. It undoubtedly offers industry a further valuable means of reducing the danger of accidents, breakdowns and general wastage, in an era when our standard of living is entirely dependent on our productivity.

Acknowledgment

This article is based on a paper by J. E. H. Brace, B.Sc., read to the Society of Instrument Technology, Cheltenham, earlier this year. The illustrations are reproduced by courtesy of Marconi Wireless Telegraph Co., Ltd., Chelmsford.

The Efficient Use of Gas in Industry

By A. E. Tyrrell

At the recent Fuel Efficiency Exhibition at Olympia, London, a series of meetings was held in the Conference Hall to discuss various aspects of the subject. We present here a slightly abridged version of a paper presented by Mr. A. E. Tyrrell, of the North Thames Gas Board.

IF all industry could save only 10% of its present fuel consumption, or take care of its next 10% increase in production without any change in its level of fuel consumption, many of the immediate anxieties about fuel would disappear. Though much has been done, it remains a disquieting fact that this country, with its vast store of knowledge, industrial experience and inventive genius, is among the least efficient fuel-consuming countries in the world. It is a challenge we cannot ignore.

The gas industry's distribution to the total thermal requirements of industry is small, but vital. It provides a refined fuel on continuous demand of a constant high quality, and its efficient utilization alone can ensure the continuation and extension of its use. The industrial gas engineer practises fuel efficiency because he must.

Applied Process Efficiency

Application of good principles of design is fundamental, however simple the plant, and this section of the paper is devoted to the practical interpretation of this fact. From the many examples of increased efficiency upon which to draw, those selected involve a typical cross-section of the more common process plant in use. Without capital spending on new plant, considerably increased efficiencies can often be obtained from existing plant. Although occasionally the increases are spectacular, 10–20% is more nearly the average.

Impressive progress is taking place in new plant. The search for new methods of heat utilization by the introduction of new techniques, by better burner design, and by extension of the use of control equipment is continuing to produce promising developments. More attention is being paid to heat recovery from exhaust gases.

Improved Plant Design in Heating of Liquids

About 20% of the gas taken by industry is used for heating liquids. Of the wide range of gas equipment used for process work, none lends itself so readily to poor design, and to the abuse of good design, as this category.

For some time research has gone on to improve the operational efficiency of simple bottom-fired vessels, of which there are large numbers in use. Much has been accomplished by inexpensive modifications; as an example of comparative efficiencies, it is interesting to give details of tests carried out on a steel tank of orthodox design which contained 15·6 gal. of water when filled to within 3 in. of the top. This tank was modified by incorporating a 1½ in. insulation jacket, re-positioning the burner to give maximum travel to the hot gases, and taking the products discharge spigot from the top of the plant instead of from the bottom. The tank was filled with exactly the same quantity of water, and was again tested under precisely similar conditions. The comparative test results are given in Table I. The increase in efficiency is even more striking than the simple and inexpensive modifications which made it possible.

TABLE I—COMPARISON OF RESULTS OBTAINED IN HEATING WATER IN EXPERIMENTAL STEEL TANKS OF ORTHODOX AND MODIFIED DESIGNS

	Orthodox Design	Modified Design
Surface area in contact with hot gases (sq. ft.)	2	9·5
Burner pressure (in. w.g.)	1·5	1·5
Time to heat to 132° F. (min.)	85	43
Gas consumed (cu. ft.)	130	72
Gas rate to maintain 180° F. (cu. ft./hr.)	21	9
Thermal efficiency heating up (per cent)	31	57
Heat flow through tank side (B.Th.U./hr.)	1,950	560
Flue gas analysis at "full on" rate—		
CO_2 (%)	2·2	8·7
CO (%)	—	—
O_2 (%)	16·4	6·8

Considerable heat losses occur also from the surface of hot liquids, and in an effort to assess the fuel saving to be expected by covering the surface, tests were carried out on a standard copper plating tank. The tank was a simple, uncased, unlagged one, containing 75 gal. of solution, and in size 4 ft. × 2 ft. × 2 ft. deep, with a solution depth of 1 ft. 6 in. It was heated by a simple longitudinal burner having a full-on rate of 90 cu. ft./hr.

Gas consumptions were carefully recorded during successive weekly periods: (1) With the tank uncovered. (2) Using a covering of plastic tubes. (3) With a covering of tubes and the addition of a sheet metal cover during the night. The results are given in Table II. These results point to the relative ease with which economies can be effected on existing plant.

Considerable progress has also been made in the design of new equipment, the most important being the development of immersion tubular heating. This has been accomplished by inserting tubes into the tank with sufficient transfer area to bring about the results required. The hot gases are passed through the tubes.

The advantages of such a system are many. Insulation of the exposed surfaces of the vessels, including the bottom, is simpler, as is ventilation when this is desirable. Working conditions are safer and better, but, most important of all, efficiencies have been raised to the order of 60–65%. It is now possible to reach and maintain working temperatures at about one-third of the cost

TABLE II.—COMPARATIVE GAS CONSUMPTION AND HEATING EFFICIENCY WITH COVERED AND UNCOVERED TANKS

Test	Average Overnight Temperature Drop, ° F. (excludes drop over weekend)	Weekly Gas Consumption (cu. ft.)	Saving Compared with Test 1 (%)
1. Solution surface uncovered day and night	52	2,880	—
2. Solution surface covered with floating plastic tubes day and night	46	2,380	17
3. As test 2, but with addition of sheet metal cover at night	43·3	2,340	19

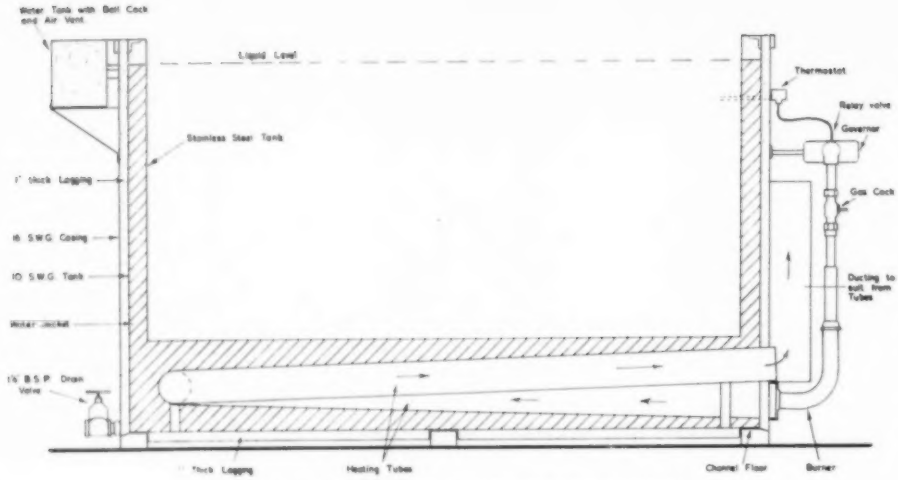


Fig. 1.—Details of immersion tubular heating.

of the plain uninsulated vessel. It may occasionally be undesirable to have the tubes in the fluid to be heated; then heating can be done through the medium of a water jacket. Fig. 1 gives details of such an arrangement, showing how the tubes are inserted into the water.

The principle of immersion heating by gas can be varied considerably. If the flow of hot gases is assisted mechanically through the tube, additional passes can be made with proportionate increase in transfer surface, and consequently higher efficiencies. The use of the single-head Hypact type burner has also contributed to greater ease of control, and much higher efficiencies in this type of plant.

Processing by Radiant Heating

There is nothing fundamentally new in the utilization of radiant energy for heating purposes. What are constantly new are the various means by which such heating is applied, and the increasingly wide range of materials being successfully treated in this manner.

Radiant heating is effected basically in two ways: (*a*) by medium-temperature black emitter panels, and (*b*) by high temperature incandescent sources. The medium temperature range is from 230 to 330° C., although in some designs the upper limit may rise to 480° C. It is in this range that radiant heating became popularly identified as infra-red. The high temperature range lies between 590 and 980° C., or even a little higher.

Through this wide range of temperatures almost all drying and finishing operations can be performed at speeds in keeping with increased production requirements. The plant can be adapted quite simply for use in a continuous production line, or, if necessary, can be remote, but connected with it by a suitable conveyor system.

The use of this type of heating in the lower range of temperatures has resulted in considerable savings in time, space, and fuel; operations formerly taking hours now take minutes. It is in this field that radiant heating is better known. The rates of heat transfer are, however, quite modest compared with those to be obtained from source temperatures above visible red. Here flux densities up to about 95,000 B.Th.U./sq. ft./hr. at 1,000° C. are available when articles are subjected to radiation from both sides.

At first, appliances for use at these temperatures were designed to meet individual requirements, but with increasing experience it has been found possible to evolve several standard designs. An extensive new field of activity for this form of heating, hitherto thought impracticable, now becomes possible.

High-temperature radiant heating brought an entire change to the firing of printed letters into Champion-Ceramic spark plug cores. Experiments showed that with a radiant surface temperature of approximately 1,000° C. the cores reached a temperature of 700° C. in four minutes, and when they were left in the heating zone for 15 minutes the temperature did not exceed 750° C. These results proved satisfactory, and two plants, each 18 ft. long were constructed. The output now exceeds 120,000 spark plug cores per eight-hour day. The time in the heating zone of the production units is approximately 5½ minutes.

The proportion of rejects on the old plant could be as high as 20%. On the new plant rejects have been eliminated. Apart from the saving of labour and valuable materials, less factory space is occupied, maintenance is smaller, and fuel consumption based on throughput is reduced by over 20%.

Automatic production is the ultimate goal of every industry, and few are faced with greater problems than those concerned in the manufacture of television and industrial instruments requiring the use of cathode ray tubes. It was the rapid growth of television, demanding large numbers of these tubes, that first presented the problem of mass producing an involved piece of apparatus requiring the application of heat throughout its manufacture, under conditions of the closest control.

Although gas plays a part in almost every stage of manufacture, it is the final and perhaps most vital operation that is now described. After the fabrication of the glass envelope, and the mounting of the gun assembly inside the tube, come the exhausting and sealing. Exhausting the tubes is done in the presence of temperatures in the range 450–500° C., and by this means the tube is thermally scoured, and gases or foreign matter released from the glass are pumped away. Before the introduction of radiant heating, this operation had been performed in convection ovens, where accurate control of temperatures and exhausting was extremely difficult. Needless to say, rejects were high and short life common.

To-day, exhausting machines are tunnel-like in formation, are lined with lightweight refractory materials to keep down thermal capacity, and are fired by a series of natural draught burners. Radiation passes to the tube from a heat-resisting steel radiating wall behind which the burners fire. The temperature rises from the entrance to the tunnel, and declines as the tube

approaches the exit. Temperature indicating takes place at a number of points around the tunnel, which is circular in form. Control of temperature is effected by motorized valves on the gas supply. There are 24 stations on the rotating table which conveys the tubes through the tunnel, each holding one tube. About twelve tubes an hour are completed by each machine. The tunnel pumps are working below, slowly exhausting the tubes and creating the high vacuum required.

The average gas consumption for each tube for this operation is approximately 33 cu. ft. Although comparison with the older method is difficult, it can nevertheless be claimed that the figure quoted is only one-third of what it was, with all the advantages of much greater output, fully-automatic control, tube failure almost eliminated, semi-automatic production, and savings in both labour and space.

Metal Melting

A good deal of attention has been directed towards the melting of non-ferrous metals, particularly the light alloys. An essential requirement is that the resultant molten metal should be altered in composition as little as possible from that of the original charge, and that it should be free from inclusions, whether solid or gaseous. Metal losses by oxidation, volatilization, and through refractories and spillage can be considerable. Consideration of these important factors has led to the choice of the crucible furnace as a means of melting, particularly in the smaller sizes. A comparison of efficiencies between the crucible and reverberatory (direct heated) furnace shows, however, a considerable advantage in favour of the latter (see Table III). Some typical figures for melting time and fuel consumption for copper are given in Table IV.

Why has the reverberatory furnace not been used to a greater extent, with the advantages so heavily in its favour? These, apart from increased efficiency, include more rapid melting, lower labour and maintenance costs, and much better working conditions. Firstly, there is the risk of greater gas absorption; secondly, there is the risk of higher metal losses.

The property of gas absorption is well known, and it is sufficient to repeat that it can be maintained within acceptable limits by control of the melting process, both in time and temperature. Here may be made not only an elementary fuel-economy observation, but a point of technical significance. To take the metal beyond the working liquid temperature, and to expose it to these conditions for longer periods than are necessary, is substantially to increase the rate of absorption. It will also increase metal loss. Practice in the United States of America is towards high-input short-run reverberatory furnaces in which the charge is melted and poured in the shortest possible time. Metal losses should be no higher than for crucible furnaces, manual control of both atmosphere and temperature being simple.

It is not suggested that reverberatory furnaces are always suitable for replacement of other types. Their use, however, in such places as die-cast foundries may bring advantages likely to improve production. In one such installation, crucible furnaces were replaced with smaller capacity reverberatory furnaces, and savings equal to 30 tons of coal a year resulted. In addition, output increased by more than 10% because of: (1) faster melting time; (2) simple continuous ingot feed; (3) less loss of time for maintenance and replacement, and (4) better working conditions, enabling the furnace to be closer to the operator.

Fig. 2.—Stereotype metal melting: arrangement of tubes in the pot.

Recognition of the need for further research and development into the whole subject of metal melting, particularly aluminium, has revealed considerable possibilities in the use of immersion tube furnaces. When gas absorption is a major problem, they provide the safeguards required. Moreover, efficiencies, perhaps exceeding 60%, now seem possible.

It is interesting to mention the application of this form of heating to a 7½ ton stereotype metal melting pot installed in the foundry of the London *Evening News*. Fig. 2 shows the arrangement of the tubes in the pot. The autoplate machine is used for casting the plates which are clamped to the rollers on the printing press. The pot forms part of the machine, and the molten metal is pumped from it into the mould, where it solidifies to form a clear impression of the matrix or flong which bears the detail of the material for the paper. The mould opens, and the moulded plate is taken off. This cycle of operation takes place four times a minute. Many of these pots are underfired; tests on both types have been made, and Table V gives figures obtained during a normal casting run.

Differences in operation make fair comparison a little difficult. It is reasonable to assume that under precisely the same conditions the immersion tube pot would have shown the efficiency to be more than 60%, and a figure of over 8·3 lb. of metal melted per cu. ft. of gas used. More than 22,000 tons of metal have been melted in this pot, and if it is assumed that an average

TABLE III.—COMPARISON OF EFFICIENCIES OF CRUCIBLE AND REVERBERATORY FURNACES

Type of furnace	Fuel	Efficiency, %
Tilting crucible furnace	Gas	7–18
Fixed reverberatory	Gas	20–30
Rotating reverberatory	Gas	22–30

TABLE IV.—TYPICAL OPERATING DETAILS OF CRUCIBLE AND REVERBERATORY FURNACES

Type of furnace	Capacity (lb.)	Fuel	Fuel Consumption per ton melted (cu. ft. 500 C.V. gas)	Melting Time
Lift-out crucible ..	250	Gas	11,000	100 lb. in 35 min.
Tilting crucible	350	Gas	11,000	200 lb. in 75 min.
Reverberatory	350	Gas	6,000	500 lb. in 35 min.

TABLE V.—TYPICAL OPERATING DETAILS OF UNDERFIRED AND IMMERSION TUBE TYPE METAL MELTING POTS.

	Duration of Run (min.)	Weight of Metal Melted (lb.)	Gas Consumption (cu. ft.)	Metal Melted per cu. ft. of Gas (lb.)	Efficiency	Maintenance Gas Rate (cu. ft./h.)
Underfired pot ..	41	8,666	1,500	5·7	40·8	175
Immersion tube pot	22·5	5,036	605	8·3	59·7	167

of 20% less fuel has been used, then over 35 tons of coal have been saved.

Thermal Treatment of Metals

The heat treatment of metals and their alloys is undertaken to produce physical properties which will render them suitable for further processing, such as rolling, drawing, pressing, or extrusion. Treatment is also necessary after fabrication into articles, tools and implements.

In gas-fired furnaces, convection and radiation are the primary means by which heat is transferred from the hot gases to the charge. The design and choice of burner system, of which there are a considerable number depends upon the temperature and conditions required. An important characteristic of any burner system is its range of stability, with which must be coupled a wide degree of control between minimum low load and full input, with no variation in the analysis of the products of combustion.

Temperatures required for the heat treatment of metals tend to become higher. The use of the Nimonic series of nickel-chrome alloys in the development of the gas turbine has brought peculiar problems in connection with thermal treatment. Design of suitable furnace structures to minimize heat losses at the higher temperatures has resulted in developments in the manufacture of both insulating and refractory materials which will improve efficiency.

Apart from the need to reduce transmission losses to as low a level as possible, the furnace structure must have high resistance to thermal stressing, and be stable at the operating temperatures. The use of hot face insulation in the construction of furnace walls, though much more in evidence in newly designed furnaces, could with advantage be adopted on a good deal of existing plant. This applies particularly to intermittently operated furnaces.

The properties of low thermal capacity and low thermal conductivity associated with these refractories are reflected in the results obtained from tests carried out on two three-ton gas-fired annealing furnaces. These are of the batch type, arranged for loading by a charging machine. These furnaces, each having principal working dimensions of 14 ft. long × 5 ft. wide × 2 ft. high to the crown of the roof, are similar in all respects except for the refractory materials used in the wall construction. No. 1 furnace has a conventional side wall structure at working chamber level of 9 in. firebrick, backed by 4½ in. high temperature insulating refractory. No. 2 furnace has similar walls of the same total thickness but built entirely of high temperature insulating refractory. In order to check the merits of the two types of wall structure, tests were carried out under normal conditions over five days; the results can be seen in Table VI.

No. 2 furnace has been working successfully since these tests for sufficient time to conclude that the mechanical strength of high-temperature insulation is

TABLE VI.—COMPARISON OF ANNEALING FURNACES WITH CONVENTIONAL (NO. 1) AND ENTIRELY HIGH TEMPERATURE INSULATING REFRACTORY (No. 2) SIDE WALLS

Day	Furnace	Annealing Temperature (° F.)	Heating Cycle, (hr.)	Load (lb.)	Total Gas Used (cu. ft. 500 C.V.)	Gas Used per lb. of steel (cu. ft.)	Reduction in Gas Consumption %
Monday ..	No. 1	750	11·75	7,107	17,740	2·50	
	No. 2	750	12·00	7,147	14,370	2·01	19·6
Tuesday ..	No. 1	900	11·25	7,342	19,590	2·67	
	No. 2	780	11·25	6,922	12,520	1·81	
Wednesday	No. 1	900	11·67	7,356	19,310	2·62	
	No. 2	900	11·67	8,433	20,400	2·42	7·64
Thursday ..	No. 1	900	11·33	7,822	18,540	2·37	
	No. 2	900	11·33	7,679	17,260	2·26	4·64
Friday ..	No. 1	650	11·50	7,480	8,820	1·18	
	No. 2	650	11·50	7,679	7,600	0·98	16·95

capable of withstanding normal use in furnaces of this kind. The application of thermal insulation in all its forms is one of the greatest potential sources of fuel saving.

There is a noticeable and desirable trend towards clean and bright heat treatment, for from this spring many production advantages. Clean heat treatment eliminates metal loss, ensures greater dimensional accuracy, and reduces very considerably, when it does not entirely remove, the need for cleaning and correcting operations following heat treatment. Although they are most frequently allied, there are nevertheless differences which distinguish cleanness from brightness; usually brightness is associated with non-ferrous and cleanness with ferrous metals. Bright thermal treatment of non-ferrous metals has been practised for many years with success, but because of the more involved nature of the plant at the elevated temperatures at which ferrous metals are treated, clean treatment has not made the same progress. Both essentially need control of atmosphere in the working chamber of an indirectly heated furnace in order to eliminate the destructive effect of oxidation. Some control in standard direct-operated plant is possible with careful handling, and is still extensively used.

High-output automatic plant is now in operation, giving a high standard of cleanness, but industry has been waiting for the development of a relatively small batch-type plant offering similar advantages. Indirect heating implies the use of muffles, or the construction of a working chamber which is isolated from the effects of combustion of the fuel. The introduction of radiant surfaces renders this unnecessary, simplifies furnace design, and makes the application of a prepared atmosphere more positive in its behaviour. In Fig. 3 will be seen a recently introduced small plant for clean heat treatment A separate apparatus prepares the atmosphere gas.

Concurrent with this development has come another of some importance dealing with the control of atmosphere in a direct-fired furnace. This work has been based on a conclusion that accurate control by automatic means of the combustion of the fuel in a condition less than the stoichiometric proportions of air results in a furnace atmosphere that is highly reducing. This development has been applied to furnace practice requiring temperatures of 1,200° C. and more. The principle of regeneration aided by special thermal pulsators is giving a higher rate of heat exchange than is usual in this type of design. Accurate control of the reducing condition has been proved by allowing stock to remain in the furnace at high temperature for long periods.

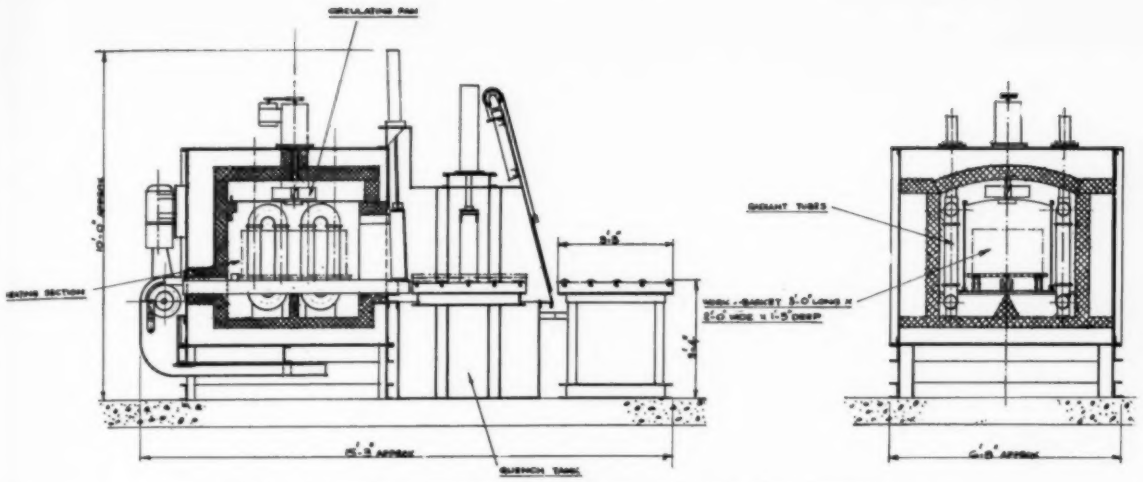


Fig. 3.—A recently introduced small plant for clean heat treatment.

A fast rate of heating, about 17 minutes to reach 1,280° C. when dealing with 15 lb. steel billets for forging, and an exceptionally low heat requirement, about 1,000 B.Th.U./lb. of metal treated, have been recorded in tests. When these results are considered with the elimination of metal loss, which may amount to 5 or 6% in forging operations, it can be seen that a considerable advance in efficiency and economy has been achieved.

It is too early to prophesy to what extent these principles may be employed in the lower temperature ranges, but research is continuing with this possibility in mind. The development of clean and bright heat treatment is of technical importance, and may bring improvements in process efficiency as high as 30%.

Efficiency as a Part of Industrial Service

Conditions of higher efficiency impose the obligation to ensure continuity. To fulfil this simple fundamental requirement has arisen an organization of research and development, of practising technicians and engineers supported by workshops and laboratories, whose main purpose is to provide on demand an easy, ready service of the right standards.

This service now exists in every part of the country, and is identified in the area industrial gas engineer. His experience of heat problems and their place in production of every kind, backed by personal knowledge of local industry, and the illimitable support of a central bureau of information, provides the right atmosphere in which to approach the problem, however complex. It is part of the service that he examines installations periodically, and makes recommendations when necessary. When, as sometimes happens, process or production changes make new design desirable he is able from his experiences, and with his supporting technical facilities, to advise on the steps to be taken. When the problem does not respond to any known practice or formula, he is able to call upon the research and development staff to assist by tests and experiments.

Each Area Board has this kind of organization, and each is represented on a central committee, which operates under the auspices of the Gas Council to co-ordinate industrial activities. The strength of this committee is to be found in the contribution made by the individual area engineers to the technical pool. It is part of their work to collect and collate data on both process and plant, and this, subject to the approval of the owners, is made available either as confidential or non-confidential information. In this way an authoritative country-wide technical service, much of it founded on established practice, is made available to anyone needing aid in connection with heat problems.

In addition to, and quite independent of, this service is the fundamental research of the London and Birmingham stations of the Gas Council, where the more involved studies of the probable future requirements of industry are carried on. Co-operation with plant manufacturers in new design and development work ensures that plant reaching the market is technically and mechanically sound. In certain circumstances the boards produce prototype plant of a design which requires development of a special nature. All this work is prompted throughout by the strong motif of efficiency directed towards increased production with lower fuel consumption.

Conclusions

The examples of increased efficiency which have been chosen emphasize the varied factors which must be taken into account when assessing total process efficiency. The limits of space alone prevented more being given.

The gas industry takes pride in the fact that, with coal of an unstable and often declining quality, it has nevertheless increased its production efficiency to 75·7%. It is estimated that if the output of gas and other products last year had been produced at the efficiency of 1948, the equivalent of an additional 1¾ million tons of coal would have been required. Moreover, the industry continues the search for natural gas, makes available to industry large quantities of coke oven gas which it receives from outside sources, and is co-operating with the oil industry in taking large volumes of refinery gases for reforming and distributing through its vast network of mains. This watchful and enterprising service ensures progress towards the ideal of high quality combined with high efficiency.

THE address of the Registered Office of Battelle Institute, Ltd., is now 24, Ryder Street, St. James's, London, S.W.1. Tel: TRAfalgar 1621.

New British Standards

DIMENSIONS OF 3-PHASE ELECTRIC MOTORS.
B.S.2083 : 1956. PRICE 3s.

The two-year old British Standard on dimensions of 3-phase electric motors (B.S.2083) has helped industry by providing for the complete mechanical interchangeability of various makes of squirrel-cage motors. Two important additions in the revised edition, now published, further strengthen this standard's usefulness. The first is the inclusion of maximum overall external dimensions, which, though still allowing for variations between individual manufacturers, will enable the purchaser to calculate the minimum space needed to accommodate any make of motor. The other main change extends the standard's cover to the dimensions of flange-mounted motors; the requirements on foot-mounted motors remain substantially the same.

The standard applies to industrial 3-phase 50 c./s. motors with continuous maximum ratings in the range 1–20 h.p. (at 1,500 r.p.m. synchronous speed) and voltages up to 650 V. With one exception, the dimensions specified are similar to those which were given in the 1949 edition of the American NEMA standard MG1, but for a given frame size the horse-power outputs have been increased; shaft dimensions and tolerances have, therefore, been adjusted to suit British practice.

DRAWING CONVENTIONS FOR LABORATORY GLASS APPARATUS.
B.S.2774 : 1956. PRICE 3s. 6d.

THIS new British Standard recommends drawing conventions for representing laboratory apparatus made principally of glass in textbooks and technical journals and reports. The conventions are intended for use both with full-size drawings and with reduced-scale drawings down to about one-tenth full size; the standard is illustrated by 10 pages of examples.

The committee which prepared this standard considered the established draughtsman's conventions listed in B.S. 308, 'Engineering Drawing Practice', and followed them insofar as they appeared appropriate to glass apparatus. Where this was not possible, the committee studied existing practice and found that conventions had not been codified or generally adopted, although some were well established.

The aim throughout has been to combine clarity and un-ambiguity for the reader with convenience for the draughtsman. The committee recognize that opinions may reasonably differ about some of the matters dealt with, especially in view of the many different purposes for which drawings of laboratory apparatus may be required. For this reason, comments on the standard and suggestions for improvement will be particularly welcome.

TERMINOLOGY OF INTERNAL DEFECTS IN CASTINGS AS REVEALED BY RADIOGRAPHY.
B.S.2737 : 1956. PRICE 12s. 6d.

THE need for rationalizing the terminology of defects in castings was realized when the Non-destructive Testing Group (formerly the Industrial Radiology Group) of the Institute of Physics initiated the preparation of the present standard. Different workers in the field, such as radiologists, metallurgists, foundrymen and engineers, commonly use various terms for one type of defect, and also at times use the same term for more than one defect. There is variation from industry to industry, and even from foundry to foundry. For example, the term "porosity" has been applied to different types of defect according to the metal or alloy concerned, and, therefore, the use of the term is to be deprecated unless it is adequately qualified, e.g., "microporosity".

The purpose of this standard is to enable the interpretation of casting radiographs to be understood without ambiguity of terminology, by those interested in the radiographic inspection of castings. To this end the terms have as far as possible been chosen to correlate the definitions with their metallurgical or foundry origin. The aim has been to select those terms which will be applicable to all the metals normally used in castings. The defects listed have been classified into five groups of associated types with sub-divisions. A separate section is included relating to diffraction mottling, which arises from purely crystallographic causes, and should not be regarded as a defect.

The terms and definitions used in the standard are illustrated by radiographs, which have been selected not only to show the salient features of the defects, but also because of their suitability for reproduction by half-tone blocks. These illustrations are intended solely to be complementary to the definitions of the defects, and not as criteria of their severity. Some of the radiographs have been supplemented by macrographs or micrographs to help in the appreciation of the nature of the defect.

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1.

Meeting Diary

(*Continued from page* 212)

21st November

Society of Instrument Technology, Newcastle Section. "Instrumentation in the Steel Industry," by J. D. MAY. King's College, Stephenson Building, Newcastle. 7 p.m.

22nd November

Institute of British Foundrymen, Northampton Section. "Carbon Dioxide Process," by DR. D. V. ATTERTON. Wellingborough. 7.30 p.m.

Institute of Metals, Birmingham Local Section. "Fatigue," by DR. N. THOMPSON. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham. 6.30 p.m.

22nd and 23rd November

Institution of Mechanical Engineers. B.N.E.C. Symposium on the Calder Hall Nuclear Power Plant. Registration required. Central Hall, Westminster, London, S.W.1. 10 a.m. each day.

23rd November

West of Scotland Iron and Steel Institute. "The Use of Oxygen in Iron and Steel Production," by D. J. O. BRANDT. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

26th November

Institution of Production Engineers, Manchester Section. "Modern Forging Practice," by H. HAYES. Reynolds Hall, Manchester College of Technology. 7.15 p.m.

27th November

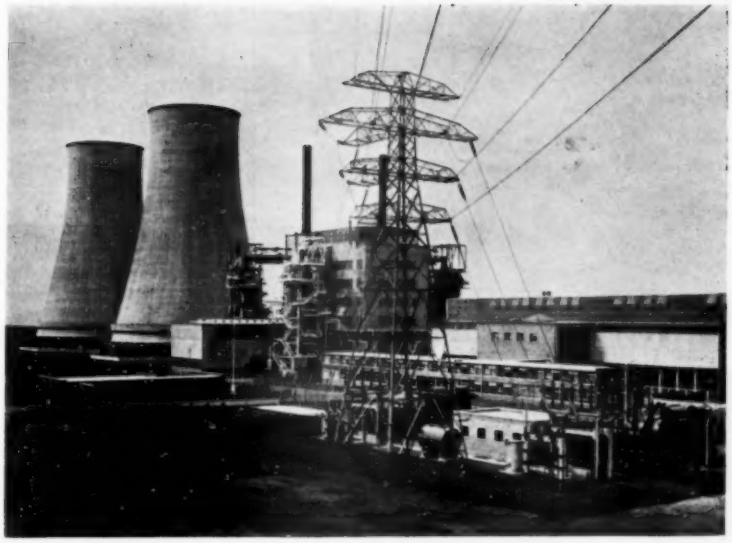
Incorporated Plant Engineers, South Wales Branch. "Inert Gas Welding Processes," Film and Lecture by MR. WOOLCOTT. South Wales Engineers' Institute, Park Place, Cardiff. 7.15 p.m.

28th November

Institution of Production Engineers, Worcester Section. "Process Development of Shell Moulding," by J. FALLOWS. The Cadena Cafe, Worcester. 7.30 p.m.

World's First Nuclear Power Station

Calder Hall Goes on Load



General view of the station nearing completion.

THE world's first large scale nuclear power station—Calder Hall—went on load on Wednesday, October 17th, when Her Majesty The Queen operated the switch which initiated the connecting of the station to the national electricity grid. Designed and built in three and a half years, in the face of considerable difficulties, Calder Hall represents an outstanding technological achievement. When it is realised that several major parts of the design had only been roughed out when construction began, and that, being the first of its kind, there was no experience and no existing example to guide the builders, the feat is even more remarkable. As Her Majesty said in her speech at the opening ceremony: "For many years now we have been aware that atomic scientists, by a series of brilliant discoveries, have brought us to the threshold of a new age." To translate those discoveries into practical commercial scale plant in so short a time has called for a huge combined operation involving chemists, engineers, metallurgists and physicists associated with the Atomic Energy Research Establishment at Harwell, the Atomic Energy Authority's Industrial Group at Risley, and the various commercial firms who undertook the construction of the plant and buildings.

General Description

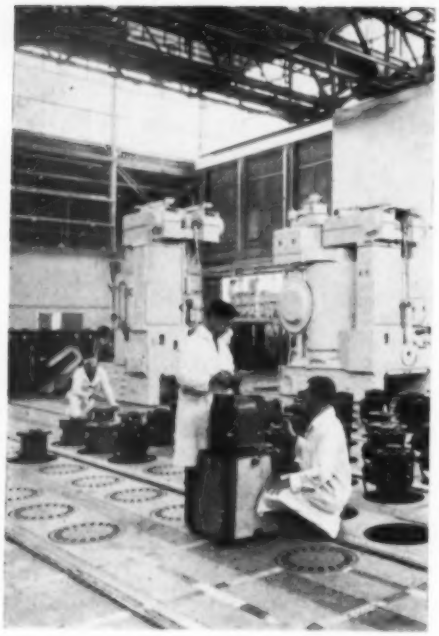
There are many points of similarity between Calder Hall and a conventional power station. In both cases electricity is generated by a turbine-driven alternator, but in the latter case steam is raised by burning oil or coal in a boiler, and in the former uranium is used to generate heat in a reactor, the heat being used to raise steam in a heat exchanger. Thus, atomic energy is obtained by burning an uncommon fuel in an uncommon way and then using the heat obtained in a quite ordinary manner.

The energy released by nuclear fission is imparted first to the two fragments into which the nucleus is split, causing them to move apart with great speed. The motion through the uranium heats the metal and it is this heat which is utilised in power production. There are two broad classes of reactor, fast-fission reactors in which the neutrons which are released in fission are used at high speed to cause further fission, and thermal-fission reactors in which neutrons are slowed down to so-called thermal energies by allowing the neutrons to pass through some light material called a moderator. The moderating action affects only the energy of the neutrons producing fission, but does not alter either the energy produced in fission or the power level at which the reactor operates.

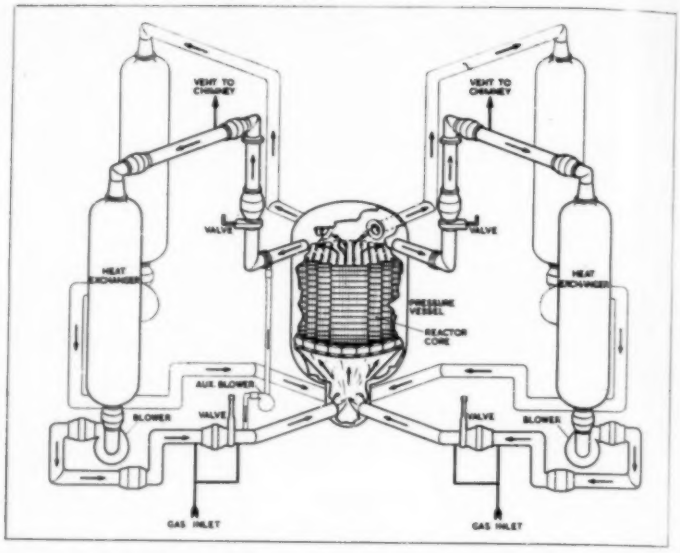
The Calder Hall reactors are of the thermal-fission type, the fuel being natural uranium and the moderator graphite. Natural uranium consists of two isotopes, uranium 235 and uranium 238, the content of the former being only 0·7%. As only this isotope is split by neutrons of low energy, only 0·7% of natural uranium is nuclear fuel. Uranium 238, however, can under neutron bombardment be transformed to plutonium 239 which will undergo fission, and therefore "burn." The Calder Hall reactors serve a dual purpose in that they generate power and make plutonium for the Atomic Energy Authority's adjacent Windscales factory, although some of the plutonium is used up in the production of heat in the reactor.

The Calder Hall site will eventually house two similar nuclear power stations with a total installed capacity of 184,000 kW., of which almost 150,000 kW. will be available to the grid. Calder Hall B station is at present under construction and is expected to be completed in 1958. Throughout this article, unless otherwise stated, reference will be made to Calder Hall A station only.

The most prominent features of the plant are the two 300-ft. cooling towers, of conventional type, situated at the seaward end. Next comes No. 1 reactor, surrounded by its four heat exchangers, then the turbine hall and, finally, No. 2 reactor and its heat exchangers. In front of the turbine hall is a building housing administrative, scientific and engineering staff. Mention will be made, in the following brief description of the plant, of some



The top of the reactor, showing charging and discharging machines.



Diagrammatic sketch of the reactor and heat exchanger arrangement.

features of metallurgical interest arising in the design or construction of particular items.

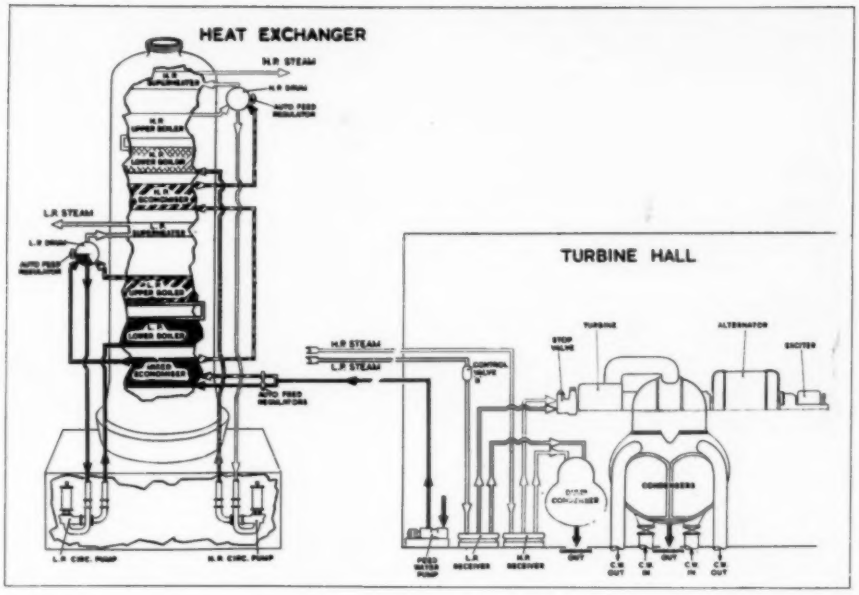
Construction of the Reactor

Greatest interest naturally centres on the reactor, which, with its heat exchangers, is the equivalent of the boiler in a conventional power station. The reactor consists of a steel pressure vessel into which is built a graphite structure housing fuel elements. The graphite is supported by flat steel plates, set on a steel grid, supported around its periphery in the vessel, and the fuel elements are stacked in vertical channels which form flow passages for the carbon dioxide coolant gas. The fuel elements are rods of natural uranium 40 in. in length and 1·15 in. in diameter, contained in magnesium alloy cans with external helical fins to assist heat transfer, so that the gas flows in the annulus between the graphite and the fin tips. Further vertical channels are provided in the graphite to take the boron steel rods which are used for controlling the reactivity of the pile by acting as neutron absorbers. The graphite structure is made up of the central core which houses the fuel elements and a surrounding reflector. A 7 ft. thick concrete biological shield encloses the entire pressure vessel, and this shield is itself protected from heat and radiation damage by a 6 in. thick steel shield and air gap between it and the pressure vessel.

The pressure vessel itself was a crucial component in the design of the plant. It takes the form of a cylindrical shell, with domed ends, set with its axis vertical. Because of its size (37 ft. diameter and 71½ ft. high) it had to be fabricated from plates on site, and the starting point in the design was the maximum thickness of steel plate which could be satisfactorily welded under such conditions. The limit was fixed at 2 in., and with a 37 ft. diameter vessel the safe working gas pressure works out at 100 lb./sq. in. and the weight of the vessel at about 300 tons. In the light of experience now available, the designers feel confident that site welding of thicker plate, perhaps up to 3 in., is quite feasible. This would enable larger pressure vessels to be built, or, alternatively, higher pressure gas might be used in a pressure vessel of the same size, with consequent improvement in performance of the reactor.

The steel used for the construction of the Calder Hall pressure vessels was an aluminium-killed mild steel of high manganese content and having good weldability and ductility. The latter property was considered most important, since no one knew how much the steel would become hardened by the action of radiation. Ways had to be formed to minimise corrosion by carbon dioxide, and the content of cobalt had to be kept to a minimum because it becomes radioactive under irradiation. After welding, which was carried out by none but experienced operators, every inch of weld was examined by X-ray to the exacting requirements of Lloyds Class I standards. Welding stresses, if allowed to remain, might

No. 1 reactor control room.

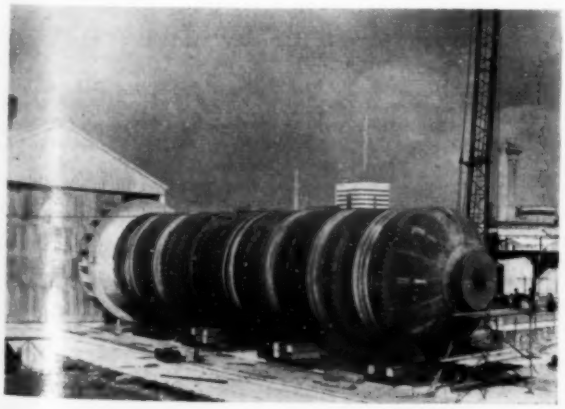


Diagrammatic sketch of heat exchanger and turbine hall arrangement.

cause failure, especially in a vessel subjected to high pressure. In order to relieve these stresses, the outside of the vessel was covered with thermal insulation and a 1,500 kW. heater shaped like a parrot cage built inside. Slowly the vessel was heated until after nearly three days it reached a temperature of 600° C. After maintaining this temperature for a day, the current was switched off and the vessel allowed to cool slowly.

Fuel Element Problems

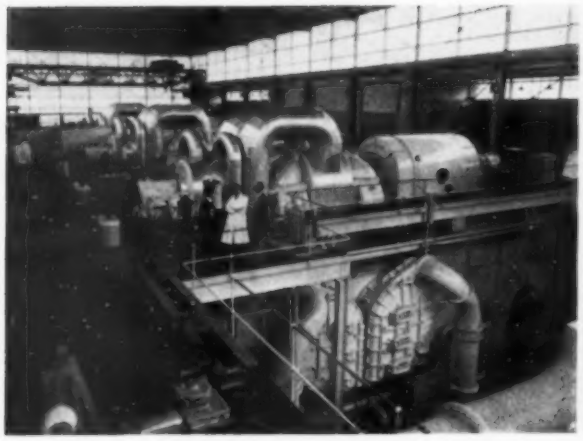
The biggest single item of development work was that on the fuel element. Nearly £500,000 was spent in establishing a design and a production line on which the element could be manufactured. The uranium rod in its can is the key component in a nuclear reactor, and is one of the most difficult to design. In order to transmit the heat generated in the uranium through the can to the carbon dioxide coolant, the can must make good thermal contact with the uranium and transfer heat efficiently to the gas on the outside. At the same time it must not be corroded by the gas or the uranium, and it must absorb neutrons to the least possible extent. Finally, it must be mechanically strong at the temperature of operation to prevent failure of the metal under the weight of the uranium inside. Of the half dozen or so metals with reasonably low neutron absorption, the best for high-temperature operation are beryllium and zirconium, but, as neither was available in the quantities required, attention was turned to magnesium alloys. A series containing small amounts of beryllium and other metals was investigated, and although the best alloy was difficult to weld, another member of the series provided a satisfactory compromise between properties and ease of fabrication.



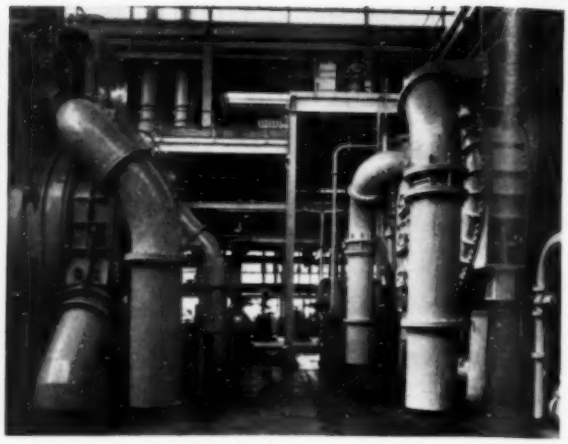
Heat exchanger shell ready for testing.

An important requirement of the uranium rod inside the can is that it should retain its shape and size in spite of the changes in temperature, and the bombardment, by neutrons and other radiations, to which it is subjected during operation. Each of the 1,696 vertical fuel channels in the graphite can accommodate six of the fuel elements, one on top of the other, so that a fully loaded reactor can hold 125 tons of uranium metal. As one precaution against bowing of the lower elements due to the weight of those above, the length of each element was reduced from the originally suggested 4 ft. to 3 ft. 4 in. Metallurgical means of improving the strength of the uranium rods, and of reducing the effects of operation were also sought. Heating and cooling and neutron irradiation produce bowing by a mechanism similar to that which causes a uranium rod to wrinkle. Research at Harwell had shown that wrinkling could be prevented if the metal contained no large grains. It was recommended, therefore, that the uranium rods should be passed through a high-frequency induction heating coil into a cooling spray.

Other problems concerning the complete fuel element which had to be overcome included the failure of cans : (1) as a result of contamination ; and (2) by a process called " ratchetting," which is due to the differential expansion of magnesium and uranium when heated. During early experimental work, cans failed by melting at temperatures much lower than had been expected.



General view of turbine hall.



Dump (left) and normal (right) condensers.

Ultimately it was found that the uranium rods had been straightened by hammering them with a lead, instead of hard-rubber, hammer, and that specks of lead had stuck to the uranium, and subsequently formed locally a low melting point alloy with the can material. Copper, aluminium, and several other common metals were found to give rise to similar troubles, and had to be rigorously excluded from the manufacturing shops.

The reactor core is made up of 58,000 graphite blocks, machined to a tolerance of 0·002 in. and interlocked in such a way as to ensure that, whatever dimensional changes the structure may undergo during the life of the reactor, the spacing and size of the fuel and control rod channels will not be disturbed. The graphite itself was processed in such a way that all possible impurities were removed, and machining and stacking in the reactor were carried out under conditions comparable in cleanliness with the aseptic conditions of an operating theatre.

Heat Exchangers

As was mentioned earlier, heat is removed from the reactor by blowing carbon dioxide at 100 lb./sq. in. pressure up the fuel element channels, its temperature rising from 140° C. at entry to 336° C. when it leaves the vessel to pass to the four heat exchangers. Each of these units contains two boilers—one generating steam at high pressure and the other at low pressure—and each has an h.p. superheater of 4,700 sq. ft. area, an h.p. evaporator of 31,500 sq. ft. area, an h.p. high temperature economiser of 15,750 sq. ft. area, an l.p. superheater of 785 sq. ft. area, an l.p. evaporator of 31,500 sq. ft. area, and an l.p. and h.p. economiser of 15,750 sq. ft. area, giving a total surface of 99,985 sq. ft.

Each heat exchanger is 80 ft. high and 17 ft. 6 in. in diameter, and the shells were constructed at the maker's works in ten sections for shipment to Calder Hall, where they were welded together with the heat exchanger axis in the horizontal position. Local preheating and post-weld stress relieving were effected by high frequency induction heating, using flexible cables as the inductor. The welds were X-rayed and the vessels pressure-tested at 300 lb./sq. in. After erection, the pressure shells were fitted with their boiler tubes, which arrived at the site in units consisting of vertical banks of horizontal tubes with projecting studs electrically welded along their length, to assist heat transfer.

Generating Plant

The generating plant is of conventional type, but, because of the comparatively low temperature and pressure of the steam supplied by the heat exchangers, the turbines are larger for their output than is usual in coal fired stations. There are four turbines in all—two per reactor—each of 23,000 kW. and running at 3,000 r.p.m. ; the generator voltage is 11,500 and the frequency 50 c./s. The steam pressure at the h.p. stop valve is 250 lb./sq. in. absolute, and the temperature 310° C. This h.p. steam per set totals 198,000 lb./hr. and makes up 77% of the total. The steam from the l.p. boiler amounts to 59,300 lb./hr. and is supplied at a pressure of 53 lb./sq. in. absolute and a temperature of 170° C.

A feature of the generating plant is the dump condenser. It is possible to divert all or part of the steam from the heat exchanger into the dump condenser instead of it entering the turbine. In this way, the steam load of the heat exchanger can be kept constant regardless of the electrical load of the turbo-alternator. The reactor can, therefore, operate at full power even when the turbo-alternator is idle. The dump condenser also enables the turbines to be started and run up with the reactor at power.

Contractors

The following is a list of the major contractors who have been concerned in the construction of the Calder Hall A power station :—

Accles and Pollock, Ltd. ; Aiton and Co., Ltd. ; Babcock and Wilcox, Ltd. ; N. G. Bailey and Co., Ltd. ; J. Blakeborough and Sons, Ltd. ; British Acheson Electrodes, Ltd. ; British Insulated Callender's Cables, Ltd. ; Cable Jointers, Ltd. ; Carbon Dioxide Co. ; Chatwood Safe and Engineering Co. ; Chesterfield Tube Co., Ltd. ; Colvilles, Ltd. ; Consett Iron and Steel Co., Ltd. ; Costain-John Brown, Ltd. ; Crossley Bros., Ltd. ; Darlington Insulation Co., Ltd. ; Dewrance and Co., Ltd. ; Electric Furnace Co., Ltd. ; English Electric Co., Ltd. ; English Steel Corporation, Ltd. ; General Electric Co., Ltd. ; Matthew Hall and Co., Ltd. ; Hopkinson's, Ltd. ; R. Jenkins and Co., Ltd. ; George Kent, Ltd. ; Lloyd's Register of Shipping ; Marston Excelsior, Ltd. ; Mather and Platt, Ltd. ; Metropolitan-Vickers Electrical Co., Ltd. ; New Western (Engineering) Co., Ltd. ; Parolle Electrical Plant Co., Ltd. ; C. A. Parsons and Co., Ltd. ; Plessey Co., Ltd. ; Pollard Bearings, Ltd. ; A. Reyrolle and Co., Ltd. ; Steel Co. of Wales, Ltd. ; Stewarts and Lloyds, Ltd. ; Strachan and Henshaw Ltd. ; Talbot-Stead Tube Co., Ltd. ; Taylor Woodrow Construction, Ltd. ; Whorton Crane and Hoist Co., Ltd. ; and Whessoe, Ltd.

A Preliminary Study of the Fatigue of Metals in Liquid Metal Environments

J. W. Martin, M.A., Ph.D., and G. C. Smith, M.A.
Department of Metallurgy, University of Cambridge.

The possible increasing use of liquid metal coolants emphasizes the importance of a knowledge of the fatigue properties of metals and alloys in contact with liquid metals. In this paper the authors present and discuss the results of fatigue tests at room temperature on amalgamated copper alloy, and at 300° C on mild steel and stainless steel in contact with liquid tin and liquid sodium, respectively.

THE problem of corrosion fatigue which arises when a solid metal is stressed in contact with a liquid metal, does not appear to have been investigated in any detail. With the possible use of liquid metal coolants in engines and in atomic energy research, the subject is clearly one which deserves the attention of metallurgists. Little previous work on this subject is reported in the literature, and enquiries have not brought to light any current work of a similar type. A certain amount of work has been reported on the phenomenon of stress-corrosion in a liquid metal environment[1], but that of Koenig and Vandenberg[2] is the only work reported on fatigue under these conditions.

Koenig and Vandenberg performed a slow fatigue test on a test bar of stainless steel, by bending it beyond the yield point and then straightening it again. Fatigue data were obtained in air and with the specimen immersed in liquid sodium. No reduction of the fatigue life was observed in any of several tests in liquid sodium. No S-N curves are published, and the temperature of test is not stated, although by comparison with other tests performed by these authors, it was probably 538° C.

In the work described below, two types of fatigue tests were carried out :—

(i) Rotating bending tests, using a Wohler-type rotating bending machine, and also a Haigh-Robertson wire testing fatigue machine. These experiments were mainly concerned with the effect of a coating of mercury on the fatigue properties of some copper alloys, in both the hard-drawn and the annealed conditions.

(ii) Push-pull tests, using a Losenhausen hydraulic machine. Experiments were performed on mild steel in contact with liquid tin, at 300° C, and some initial experiments using 18/8 stainless steel in contact with liquid sodium, also at 300° C. To simplify the experimental arrangement in the push-pull tests, the liquid metal was contained within hollow test-pieces.

The solid metals used were all of commercial purity, and their analyses are given in the appendix to the paper. The liquid metals were commercial high purity metals.

Tests on Amalgamated Copper Alloys

Wohler Tests

(a) 70/30 *Brass*

A series of experiments was made using annealed 70/30 brass specimens. The specimens were machined from hard-drawn 0·50 in. diameter rod, the gauge length being ground by means of a profiled emery wheel.

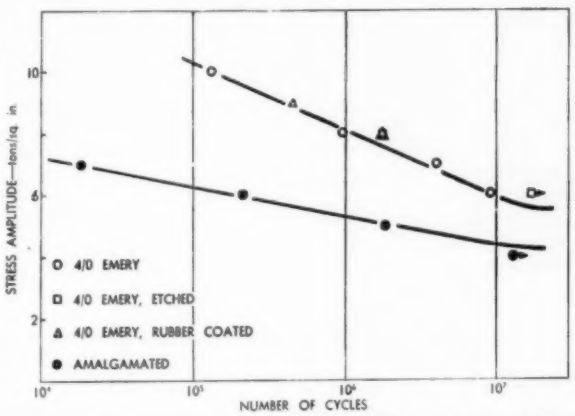


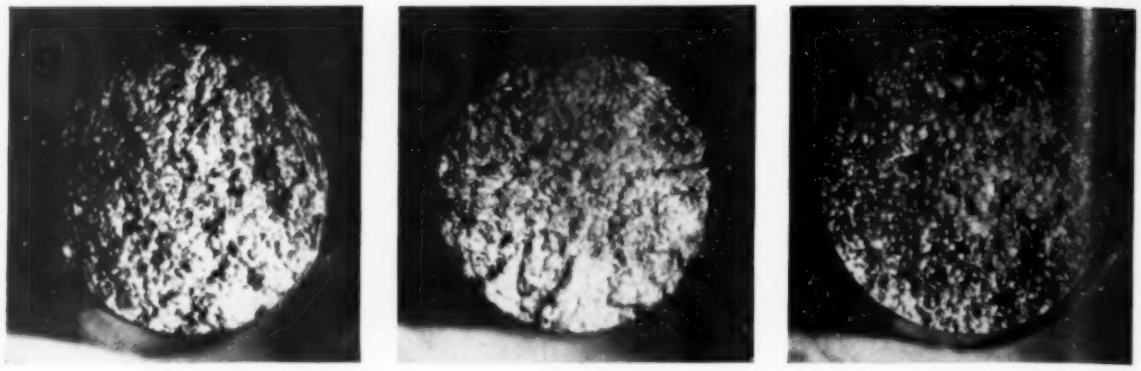
Fig. 1.—S–N curves for Wohler tests on 70/30 brass, before and after amalgamation with mercury.

The gauge length diameter was left approximately 0·005 in. oversize, and the specimens were annealed at 455°C. (± 5°C.) for one hour in an atmosphere of argon. They were then ground to size using increasingly finer grades of emery paper, the final surface finish being 4/0 emery.

An S-N curve was determined for the material in this condition, and the results are shown in Fig. 1. To amalgamate the test section it was found necessary to etch it in 10% ferric chloride solution before immersion in mercury. To investigate the effect of such an etch on the fatigue properties, two etched specimens were tested. The results of these tests also appear in Fig. 1. It appears that etching tends to improve slightly, rather than worsen the fatigue properties. This is possibly associated with the removal of disturbed material from the surface layers during the etching operation.

An S-N curve was next determined for specimens with a thick coating of mercury applied after etching the metal The results appear in Fig. 1. and it will be seen that at all stresses the life is considerably reduced. The effect appears to be a minimum in the region of the fatigue limit (based on 10^7 cycles), and increases rapidly as the stress amplitude is increased.

The fracture surfaces were examined in all cases with a low power binocular microscope. The first series of specimens, i.e., unetched and unamalgamated, showed fractures which were clearly intergranular (Fig. 2*a*) and this was confirmed by a sectional examination. The



(a) (b) (c)

Fig. 2.—Fracture surfaces of 70/30 brass Wohler specimens : (a) 4/0 emery surface ; (b) rubber coated surface ; (c) amalgamated surface. ×5 (approx.)

intergranular nature of these fatigue fractures is probably associated with a corrosion-fatigue effect due to the presence of moisture and oxygen during the test[3]. To investigate this, a fatigue test was carried out, excluding air and moisture from the surface, the method used being one developed by Brown and Smith[4]. The specimen is thoroughly degreased by washing in alcohol and then acetone, and, when dry, a solution of rubber in carbon tetrachloride is painted on the gauge length. As soon as this application has dried, a second coat is rapidly applied so that the original coat is not disturbed. A third coat of the solution is applied in a similiar way.

The results for two specimens tested under these conditions also appear in Fig. 1. There is no great improvement in fatigue life over the uncoated specimens, although Brown and Smith report that, in certain materials, the fatigue limit (based on 10^7 cycles) is raised by this surface treatment.

The fracture surfaces were examined under a binocular microscope, and in this case the fracture near the surface of the specimen no longer appeared intergranular, indicating the effect of the coating. However, a certain amount of intergranular fracture still appeared to be present towards the centre of the specimen (Fig. 2*b*). In the case of the amalgamated specimens, intergranular failure occurred over the whole of the fracture surface, although the zone wetted by mercury did not extend to the centre of the fracture (Fig. 2*c*).

(*b*) 60/40 *Brass*

A series of experiments was also made to determine the effect of a coating of mercury on the fatigue properties of a 60/40 brass. An S-N curve was determined for the brass in the as-extruded condition, with a 4/0 emery surface finish. The curve appears in Fig. 3, from which the fatigue limit (based on 10^7 cycles) is estimated at 12 tons/sq. in. The S-N curve for etched and amalgamated specimens is also shown in Fig. 3, and a decrease in fatigue life at all stresses is observed. The fatigue limit (based on 10^7 cycles) is estimated at 8 tons/sq. in.

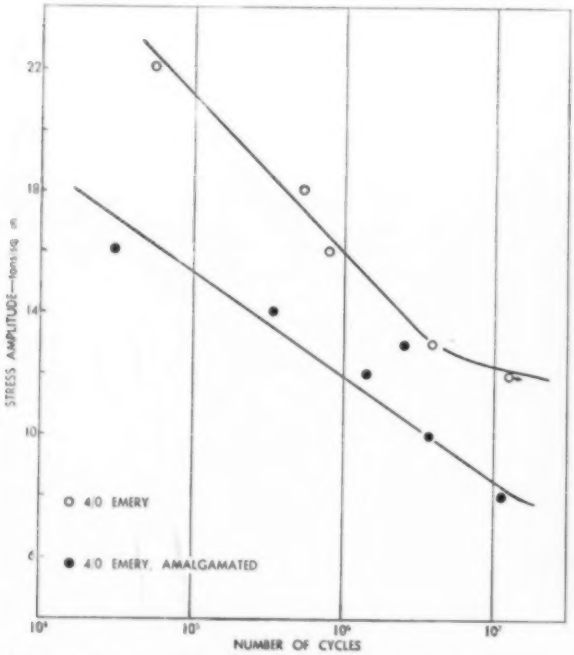


Fig. 3.—S-N curves for Wohler tests on 60/40 brass, before and after amalgamation with mercury.

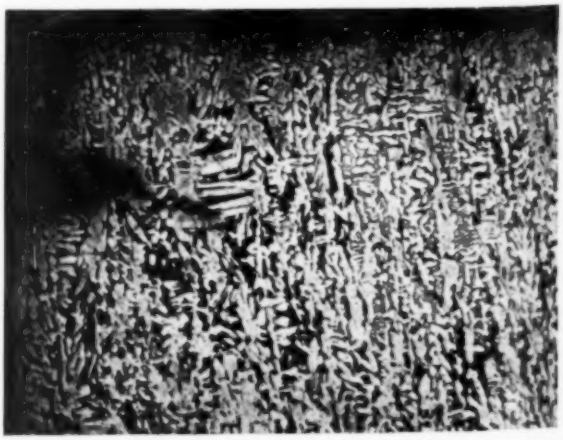


Fig. 4.—Microsection through fatigue fracture in amalgamated 60/40 brass (Wohler specimen) showing subsidiary crack. Etched ferric chloride. ×100

No experiments were conducted on this material to determine the effect of the etch in ferric chloride prior to amalgamation. It is considered, however, by comparison with the results described above for 70-30 brass, that the effect of the mercury will be considerably greater than any effect due to etching.

Specimens fractured with and without mercury were sectioned and compared under the microscope. Fig. 4 shows a section through the fracture of an amalgamated specimen and a subsidiary crack is also in evidence. The path of the cracks tends to follow the *beta*-matrix rather than run through the *alpha*-phase. In the case of the non-amalgamated specimens, the path of the fracture seemed random. In the case of amalgamated specimens it was observed that in all cases partial amalgamation of the fracture surfaces had occurred : the lower the fatigue stresses, the greater the depth of penetration of the mercury.

Haigh-Robertson Tests

A number of hard drawn copper-alloy wires (0·1 in. diameter) were tested, to determine the effects of amalgamation. The wires were polished at the centre, i.e., where the highest stress was present during the test, down to 4/0 emery, the final emery scratches being longitudinal.

(a) 70/30 *Brass*

The S-N curves are shown in Fig. 5. The upper curve refers to material with a 4/0 emery surface condition, and the lower curve was obtained by amalgamating the surface, after an etch in 10% ferric chloride. The general relationship between the two curves is similar to that obtained with the annealed material, in the case of the Avery tests, described earlier. The decrease in life on amalgamation is a minimum in the region of the fatigue limit (based on 10^7 cycles), the effect becoming increasingly marked as the applied stress is increased.

(b) Copper-Tin Alloy

The S-N curve for unamalgamated material is represented by the upper curve in Fig. 6. The fractures obtained had characteristically smooth appearances and were approximately normal to the axis of the specimen.

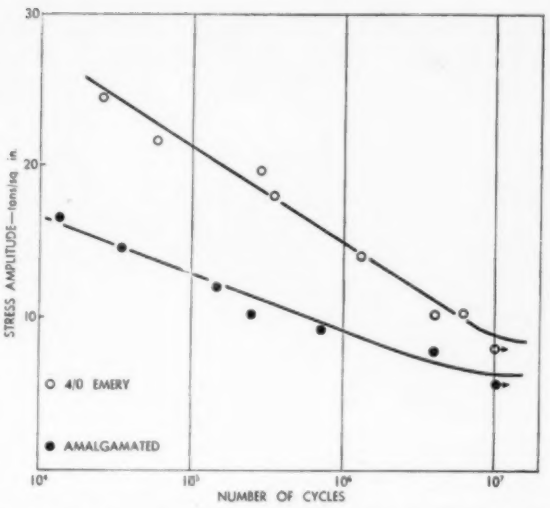


Fig. 5.—S–N curves for Haigh-Robertson tests on 70/30 brass before and after amalgamation with mercury.

Amalgamation did not affect significantly the life of the material. At stresses above about 14 tons/sq. in. high damping losses caused the specimen to become very warm during the test, with the result that the mercury distilled off the surface at the centre of the specimen. This effect is clearly a limitation of the testing method. At the lower stresses employed, however, the mercury remained on the surface, but the fatigue life was not decreased.

The nature of the fatigue fracture obtained with this material after amalgamation was especially interesting Considerable longitudinal cracking was observed on the surface, and the fracture surface consisted of a longitudinal split about 1 in. long, passing in a jagged manner to the surface (Fig. 7). The effect is probably associated with the penetration of mercury along longitudinal inclusions, as examination of the roots of such longitudinal cracks showed them to be associated with elongated non-metallic inclusions.

(c) Copper-Cadmium Alloy

The results of these tests are shown in Fig. 6. There appears to be no marked effect on the fatigue life when the surface is amalgamated. At the highest stresses employed, heating of the specimen again caused the mercury to distil off the test section, but in the region of the fatigue limit (based on 10^7 cycles), the specimen surface remained amalgamated throughout the whole of the test.

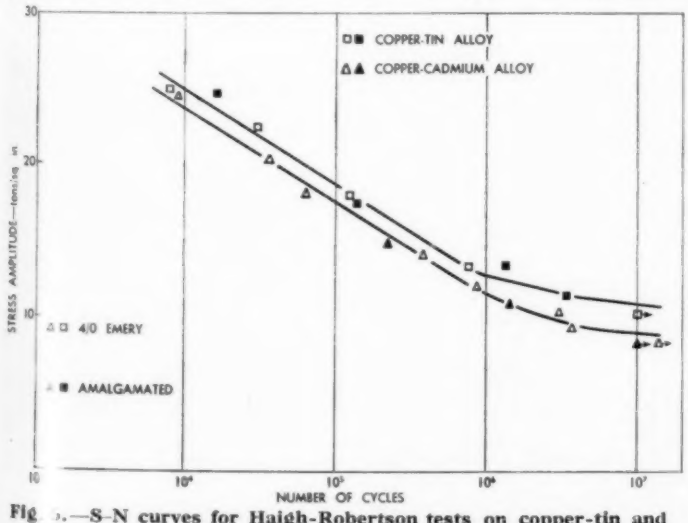


Fig. 6.—S–N curves for Haigh-Robertson tests on copper-tin and copper-cadmium alloys, before and after amalgamation with mercury.

High Temperature Push-Pull Fatigue Tests with Liquid Tin and Liquid Sodium

The Losenhausen fatigue testing machine employed is an hydraulic machine of six metric tons capacity, and in the tests described was operated at a frequency of 1,000 cycles/minute. The specimen was held in two grips, shown in Fig. 8, which screwed into the

Fig. 7.—Fatigue fracture surfaces of amalgamated copper-tin alloy (Haigh-Robertson specimen). The upper half is rotated 90° about its axis with respect to the lower half. ×4½

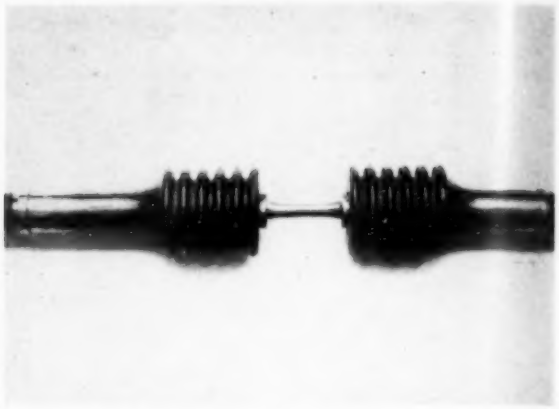


Fig. 8.—Fatigue specimen in the high temperature grips of the Losenhausen machine: the tests are carried out with the specimen in the vertical position. ×⅔

chucks of the machine. They were designed by the manufacturer to produce a zone of approximately constant temperature along the length of the specimen. A vertical electric resistance furnace was then placed around the specimen and grips. There were three radial holes from the outside to the centre of the furnace tube, at levels corresponding to the ends and centre of the specimen when in position in the furnace. In the upper hole was a platinum/platinum-rhodium thermocouple for temperature measurement, and in the lower hole was the temperature controller thermocouple. The temperature distribution over the specimen was determined by inserting a thermocouple in each of the three radial holes in turn, and adjusting until the readings agreed to within ± 2° C. Before screwing the specimens into the grips, the threads were lubricated with graphite, to assist in the removal of the specimens at the end of the test.

The Specimens

The materials tested were mild steel, in contact with liquid tin, and 18/8 stainless steel in contact with liquid sodium. In each case the liquid metal was contained within the specimen, which had a 0·25 in. diameter hole bored along the axis. The test section was 1 in. long and 0·436 in. external diameter, and was formed by grinding with a shaped emery wheel. This produced smooth fillets of constant profile. Each specimen was prepared with an exterior surface finish of 4/0 emery, the axial hole being carefully reamed.

The liquid metal was sealed within the specimen in the following manner. A 0·312 in. B.S.F. thread was tapped for 1·375 in. down the axial hole at each end of the specimen, and then there were inserted two steel grub-screws 0·4 in. long, separated by a plug of annealed high-purity aluminium. A tight joint was formed, and, as aluminium has a greater coefficient of expansion than steel, a rise in temperature would help to maintain the joint air-tight.

The filling of the mild steel specimen with tin was carried out by using a 0·25 in. diameter rod of tin, prepared by casting the molten metal into a heated silica tube of the requisite bore. A suitable length was cut off, and inserted into the specimen to fill the un-

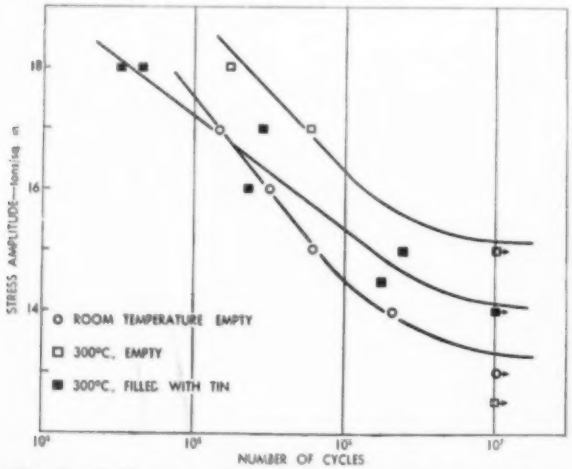
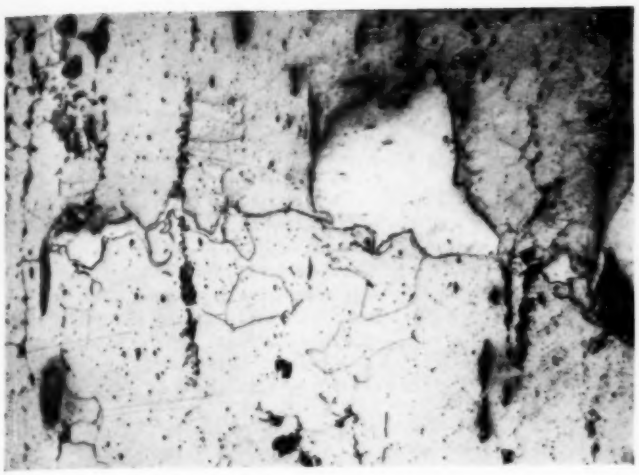


Fig. 9.—S–N curves for mild steel, with and without liquid tin.

Fig. 10.—Microsection through steel-tin interface in unfractured fatigue specimen after 10^7 cycles at 12·5 tons/sq. in. Etched 2% nital. ×250



(*left*)
Fig. 11. — Micro-section of mild steel fatigue specimen fractured at 300° C. in contact with liquid tin. Etched 2% nital. ×500

(*right*)
Fig. 12. — Micro-section of the same specimen as Fig. 11, showing penetration of liquid tin round sulphide inclusion. Etched 2% nital. ×500

tapped portion. The ends were then sealed by the method described above.

To fill the stainless steel specimens with sodium, one end of the specimen was sealed with two stainless steel grub-screws separated by an aluminium plug. The specimen was placed in a vacuum chamber, and surrounded by a resistance heater. Liquid sodium was then run in under vacuum, and the specimen sealed off in vacuum by means of two more grub screws and an aluminium plug. The seal formed was such that after a test at 300° C. lasting ten days, a sectioned specimen revealed the sodium apparently unoxidised.

Experimental Results

(*a*) *Mild Steel with Liquid Tin.*

Three series of experiments were made with mild steel specimens. First, an S-N curve was determined at room temperature, and subsequently the life at a number of alternating stresses was determined at 300° C. and a tentative S-N curve drawn as shown in Fig. 9. It will be seen that the fatigue limit is raised at the elevated temperature, and the life is increased at stresses above the fatigue limit. This is due to strain-ageing, which would have its maximum effect at about this temperature of testing.

Tin was chosen as the liquid metal inside the mild steel specimens as it has long been known that it will penetrate stressed steel[5]. The S-N curve thus obtained at 300° C. also appears in Fig. 9 The fatigue limit is lowered, and the life at stresses above the fatigue limit is reduced, compared with the unfilled specimens at elevated temperature. As in the case of the amalgamated specimens described previously, the proportional decrease in life is greatest at the higher stresses employed and least in the region of the fatigue limit.

A number of metallographic examinations was carried out to investigate any cracking or penetration of the steel by the molten tin. A tin-filled specimen was tested at 300° C. with an alternating stress of 12·5 tons/sq. in. and was unbroken after 10^7 cycles. Metallographic examination showed that the steel had been wetted by the liquid tin, and considerable interaction had taken place to produce the layer of inter-metallic compound shown in Fig. 10. In spite of this, no deep tin penetration leading to fracture had taken place. A detailed metallographic examination was also made of a fractured specimen, and a typical photomicrograph is shown in Fig. 11 of a region near the main fracture where considerable penetration by the liquid tin had taken place. The intergranular nature of the tin penetration is clearly seen, and in this particular case a section of the penetrated steel has come away, and an ' island ' of tin has formed within the specimen. A further feature of the penetration was that it frequently occurred more rapidly around the sulphide inclusions in the steel, although these were, in fact longitudinally orientated in the specimens, so that the penetration in this case was not in the direction of high normal stress (Fig. 12).

(*b*) 18/8 *Stainless Steel with Liquid Sodium*

Only a few tests have been carried out so far with this system at 300° C., but, although there is a considerable scatter, the results shown in Fig. 13 indicate that the S-N curve for sodium-filled specimens is probably much the same as that for unfilled specimens.

However, although the life of sodium-filled specimens does not seem significantly different from empty specimens tested under the same conditions, a number of cracks have been observed in sodium-containing specimens. Fig. 14 shows part of the main fracture, as well as the inner wall of the specimen. A number of subsidiary cracks are evident, but a similar specimen tested without liquid sodium showed no evidence of cracking.

No evidence of attack by liquid sodium could be observed on examining specimens which had been tested up to 10^7 cycles without failure. These specimens, on sectioning, still contained sodium, and were not oxidised, which is confirmatory evidence for the efficiency of the sealing technique adopted for the specimens.

Discussion

A review has been published recently[6] of investigations of stress cracking of copper and brass by molten metals. It has been observed that soft annealed copper is susceptible to intergranular stress-corrosion cracking[7] when amalgamated with mercury. On the other hand, Moore *et al.*[8] report that no weakness was found in cold-rolled copper when stressed in the amalgamated condition.

With regard to stress corrosion tests on brasses [7,9,10,11] when in contact with liquid metals, cracking is intercrystalline in the pure *alpha* and pure *beta* alloys. In the

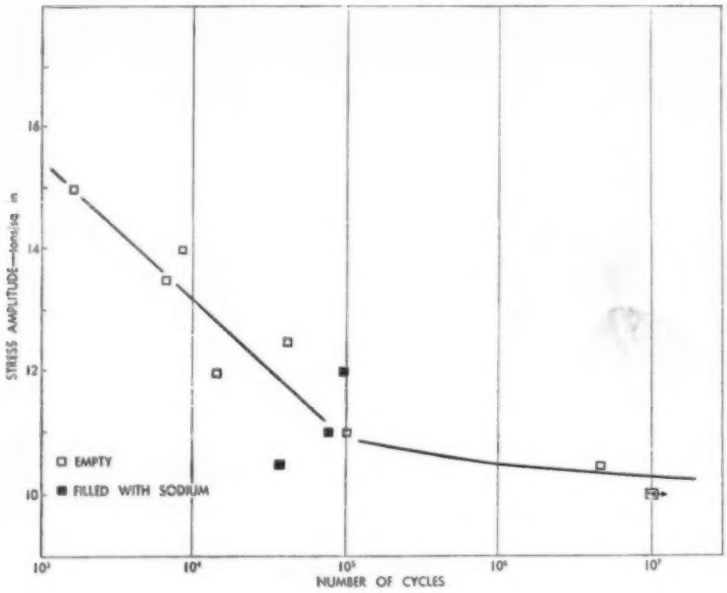


Fig. 13.—S-N curves for 18/8 stainless steel with and without liquid sodium.

alpha-beta alloys, there is often a tendency for the penetration to follow the phase boundaries or to show preference for the *beta*-phase.

The experimental results described in the present work indicate that a similar state of affairs may exist with fatigue stressing. Bailey and King[6] state that the general run of evidence indicates that stress-cracking by molten metals, of copper and its alloys with zinc, is favoured by the presence of long, smooth grain boundaries. On this basis, it would appear that previous cold working should have an inhibiting effect on such stress-cracking. However, although the effect of amalgamation has been found to be negligible on the fatigue properties of cold-worked copper-tin and copper-cadmium alloys, the cold-worked 70-30 brass is weakened to about the same extent as the annealed material.

The S-N curve obtained for the mild steel—liquid tin, system, indicates that, as with the brasses and mercury the effect of the liquid metal on the endurance is a minimum in the region of the fatigue limit, and increases with increasing applied stress. The effect of the inclusions is also similar to that obtained in the Haigh-Robertson tests on the deoxidised copper, when the liquid metal appeared to penetrate rapidly along the inclusion/metal interface.

The tendency to intergranular penetration of the molten tin into the steel may be a function of the value of the dihedral angle between ferrite and liquid tin. It would be of interest to compare behaviours in systems where the dihedral angles are different, and where intercrystalline diffusion may not occur so readily under stress.

Another aspect of the problem which calls for further investigation is the nucleation and progress of fatigue cracks under these conditions. The presence of intermetallic compounds at the liquid metal-solid metal interface should be of importance in this respect, although the results obtained with the mild steel and liquid tin indicate only a small effect. The plasticity of intermetallic compounds at the testing temperature may be the important factor controlling crack formation and propagation in such cases. The interfacial energy between the liquid and solid metal may also be important, as a low value for this may result in an easier formation and extension of the fatigue crack.

The absence of any marked effect of molten sodium on the endurance of stainless steel at 300° C., is in agreement with the work of Koenig and Vandenberg. The source of the transcrystalline cracks observed in the fractured specimens is not clear, but their presence evidently does not necessarily lead to early failure.

When an effect is observed, under the conditions of liquid metal corrosion fatigue described above, it is interesting to contrast it with other forms of corrosion fatigue. Under corrosive conditions, a lowering of the fatigue limit is often observed, with comparatively little effect at higher stresses. This is clearly connected with the time-dependent nature of the corrosion. However, when a liquid metal is present, the effect appears to be at a minimum near the fatigue limit, and increase with the applied stress amplitude, although there is insufficient evidence to say whether this is always the case.

(*Continued on page* 238).

Fig. 14.—Microsection showing transgranular cracks near fatigue fracture in stainless steel in contact with liquid sodium at 300° C. Etched Marble's reagent ×250

Rare Earths in Steel Castings

By W. J. Jackson, M.Sc.(Eng.), A.R.I.C., A.I.M.

British Steel Castings Research Association

Comparatively little attention has been given to the application of the rare earths in cast steels, but from the limited published work on the subject it would appear that rare-earth additions improve ductility and impact properties, reduce susceptibility to hot tearing, and increase fluidity. Both hardenability and weldability appear to be unaffected.

THE rare earth group of metals retains a name reminiscent of the days of alchemy, when the term "earth" was used to describe certain materials of earthy appearance, which were insoluble in water and without metallic lustre. It was later discovered that "earths" were, in fact, oxides, but in this case the terminology has been retained to the present day.

The elements to which the term "rare earths" strictly applies are those grouped together in the Periodic Table, having atomic numbers 57 to 71 and named, respectively, lanthanum, cerium, praseodymium, neodymium, illinium (promethium), samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutecium. Yttrium (atomic number 39) is frequently included in this group, on account of its association with rare earths in certain ores. Scandium (atomic number 21) is another metallic element often included with the rare earths, because of its very similar properties.

The prefix "rare" was used by the early chemists because they believed that this particular group of elements existed only to a small extent in the earth's crust. While this is partly true, in that some members of the rare-earth group are relatively scarce in nature, others are quite plentiful. For example, cerium is more abundant than tin, silver, gold, cadmium, mercury, antimony, tungsten or platinum; and lanthanum, yttrium and neodymium are each more abundant than lead.

The chemical properties of the rare-earth elements are remarkably similar. Consequently, while separation of these elements from others is not a difficult task, their separation one from the other is lengthy and uneconomical. It is of interest to note that as many as 40,000 operations have been necessary to isolate and purify some of the rare-earth elements. Since 1945, however, a more rapid and efficient method, based on ion-exchange, has been developed in connection with atomic energy interests, since rare earths are an important by-product of atomic piles.[1] However, for commercial applications, mixtures of rare-earth metals or oxides are generally used.

A characteristic of these elements is the high heat of formation of their oxides, no other metal having a higher affinity for oxygen. *Mischmetall*, which is an unseparated reduction product of a natural mixture of rare earths, is, therefore, a better deoxidising agent than aluminium. In addition to this property, the rare-earth elements have a strong affinity for hydrogen, nitrogen and sulphur.

Sources of the Rare Earths

Monazite sands, occurring in parts of India, Brazil, South Africa and the Dutch East Indies, have, until recently, constituted the main sources of the rare earths. Following an intensive search in the United States, other larger deposits have been revealed, the most promising of which is bastanite, found in a large barite-carbonate rock deposit in California. Other useful deposits occur in Texas, North Carolina and Colorado. It may be of interest to note that in a comparison of the scarcity of certain materials under conditions of "full mobilization,"[2] a U.S. Defence Directive listed iron as 1·0, nickel as 20·5, rare earths as 80·0, molybdenum as 85·0 and cobalt as 230·0.

In the refining of monazite ores, the final stage is the electrolysis of a mixture of rare-earth chlorides, from which is produced a metallic mixture called *mischmetall*.* A representative analysis is :—

Cerium	45–55%
Lanthanum	22–30%
Neodymium	15–18%
Praseodymium	up to 5%
Other Rare Earths	2%
Iron	0·5–3·0%

Separation of the component metals involves fractionation on a laboratory scale, prior to electrolytic refining. In view of these difficulties, the metals are not normally separated for industrial use.

As previously mentioned, a method of separation called the "ion exchange" method has been developed, but it is expected that the more common rare earths, cerium and lanthanum will still be separated by the conventional method.[3]

Functions of Rare Earth Additions to Steel

The precise mechanism by which rare-earth additions effect the reported improvements in steels is not yet known. It seems probable that no single factor will account for these changes, particularly as the literature indicates that the metallic form is most frequently added to low alloy steels, and the oxide, or less commonly the fluoride, to high alloy steels. The possible functions of these additions will, therefore, be discussed.

Addition of the Metal

(*i*) *As a Deoxidant*

It has been observed that when rare-earth metals are added to steel in addition to the normal deoxidants,

* A similar mixture, produced in the United States, is sold under the proprietary name of LanCerAmp.

TABLE I.—COMPARISON OF THE PROPERTIES OF QUENCHED AND TEMPERED 1¼% MANGANESE STEELS DEOXIDISED BY VARIOUS TREATMENTS[4]

Tempering Temperature	Finishing Treatment	Tensile Strength (tons/sq. in.)	Charpy V-notch Impact Strength at −40° C. (ft.-lb.)	Reduction in Area (%)
495° C.	Regular[1]	58·0	21·5	35·0
	Selenium[2]	58·0	27·0	40·5
	Rare Earth[3]	58·0	32·5	48·0
605° C.	Regular[1]	49·0	31·0	44·0
	Selenium[2]	49·0	34·0	47·0
	Rare Earth[3]	49·0	40·5	58·0

[1] Deoxidised with aluminium and calcium-manganese-silicon.
[2] Deoxidised with aluminium and selenium.
[3] Deoxidised with aluminium, rare-earth metal and calcium-manganese-silicon.

the sulphide inclusions are small, globular and randomly distributed,[4, 5] indicating their precipitation early in the solidification process, due to low solubiiity. By the use of rare earths, together with aluminium, there would appear to be less danger of forming the deleterious Type II* inclusions associated with the use of aluminium alone, when this is added in a critical amount.[6]

However, Lillieqvist and Mickelson[4] are of the opinion that the change in form of the sulphide inclusions is not entirely responsible for the improvements in mechanical properties, as other deoxidisers, such as selenium, cause sulphide inclusions to be changed to Type I without markedly improving the mechanical properties. The data which they presented to illustrate this point can be seen in Table I. The selenium steel exhibited Type I globular inclusions, as did the rare-earth steel, but did not develop such high ductility and impact strength as did the latter.

Lillieqvist and Mickelson have also demonstrated that a rare-earth addition can replace aluminium as a deoxidising agent, since it is as effective in eliminating pinhole porosity. They conclude that "to obtain the maximum benefits from this alloy, it must be protected from traces of oxygen in the steel by proper additions of aluminium."

(*ii*) *As an Alloying Constituent*

Following their demonstration that selenium also alters the inclusion type, but without greatly improving the mechanical properties, Lillieqvist and Mickelson conclude that the alloying effect of the rare-earth metals must play an additional part in the improvement. However, no differences were revealed between the microstructures of the rare-earth-treated and the untreated steels, in the normalised and tempered or quenched and tempered conditions.

It is interesting to note that a radioactive tracer technique[7] has indicated that in high alloy steels the rare earths are uniformly distributed throughout the matrix. In the amounts added, complete solubility may have been expected, since cerium is soluble to the extent of 0·5% in both *alpha* and *gamma* iron.[8]

(*iii*) *As a Sulphur Remover*

An investigation of the effects of certain materials on sulphur removal from steel was, in fact, responsible for the discovery that rare-earth additions improve the mechanical properties of certain steels. Those who have studied the effect of rare-earth additions[2, 4, 5, 9, 10] are largely agreed that under production conditions

TABLE II.—SUMMARY OF THE EFFECT OF RARE-EARTH ADDITIONS ON SULPHUR REMOVAL IN DIFFERENT STEELMAKING PROCESSES.

Steelmaking Process	Source	Effect of Rare Earth on Sulphur Reduction
High Frequency (Basic)	Lillieqvist & Mickelson[4]	No effect
	Beaver[2]	No effect
Open Hearth (Basic)	Lillieqvist & Mickelson[4]	Reduced by 4 to 5 points
	Russell[9]	Reduced by 4 to 5 points
Electric Arc (Acid)	Lillieqvist & Mickelson[4]	Reduced sometimes by 17 points, usually 4 to 5 points.
Electric Arc (Basic)	Lillieqvist & Mickelson[4]	Consistent reduction

sulphur reductions can be achieved, but reports concerning the extent of the removal have not been consistent. Discrepancies appear to have arisen when various steelmaking processes have been used.

For example, Lillieqvist and Mickelson[4] and Beaver[2] found that, when melting in a basic-lined high-frequency furnace, no sulphur reduction at all occurred. With basic open-hearth melting, the former authors report a reduction in sulphur by about 4 to 5 points.* Results reported by Russell[9] on basic open-hearth steels show that he obtained similar reductions, although in most cases his additions were made in the ingot mould, which generally resulted in larger reductions. Russell also demonstrated that the efficiency of the sulphur removal depends on the amount initially present, and increases as initial sulphur content increases.

In the case of acid electric arc furnace melting, sulphur reductions up to 17 points have been reported, although more frequently they were of the order of 4 points.[4] Altogether, results were inconsistent, and the opinion has been expressed that the use of rare-earth metals in basic electric arc furnaces appears considerably more promising.[4] These observations are summarised in Table II.

The mechanism of sulphur removal by rare-earth metals appears to involve the formation of a relatively stable sulphide phase. This must rise, because of density differences, and enter the slag which covers the molten metal in the pouring ladle. Russell's work[9] is in agreement with this, for when rare-earth additions were made to the freshly poured ingot mould, normal segregation of sulphur was eliminated, but the cerium sulphides in rising were trapped by the ingrowing columnar crystals.

What happens to the rare-earth sulphides when they reach the slag probably depends on the temperature and nature of the slag itself. If it is basic and of a reducing nature, conditions will favour the retention of the sulphur in the slag: high slag temperatures also favour this. Acid slags which tend to be oxidising, and also neutral slags, will favour oxidation of the rare-earth sulphides. Under these conditions, sulphur will return to the metal as iron or manganese sulphides (which are soluble in liquid steel), and the rare earth will presumably be lost as oxide in the slag. It is considered that the inconsistencies in sulphur removal experienced in the different steelmaking processes may thus be explained.

Addition of the Oxide or Fluoride

Additions of rare-earth oxides and fluorides have been made chiefly with a view to improving the hot workability of high alloy steels, and it is this field which has

* Nomenclature of Sims and Dahle. See reference No. 6.

* A "point" in this context means 0·001%.

been most widely investigated. While rare-earth metal has also been found suitable for converting inherently hot short austenitic steels into hot workable alloys,[10, 11] interest in the oxide may be accounted for, among other reasons, by its favourable price compared with the metal.* Rare-earth oxides are generally used together with suitable reducing agents, such as calcium boride and sodium nitrate.†

It is reported that no recovery of rare earths takes place after addition of the oxides,[10, 12] nor is there any sulphur removal.[9] Grain refinement is said to result, and this may be a contributory factor to improved hot workability. However, rare-earth oxides will not convert an inherently hot short alloy into easily hot-worked material, it being stated that rare-earth metal is required for this purpose.[2, 10] The mechanism by which rare-earth oxides impart improved hot-working properties to alloy steels is at present not understood.

It has been suggested that hot workability is improved by a rare-earth addition effecting removal of trace elements such as lead, tin and silver,[2, 12, 13] which are known to impair hot workability by the formation of low melting point sulphides. An alternative suggestion is that hot workability is improved by the rare earth preventing diffusion of oxygen during hot working.[10] It is not clear from the literature whether these hypotheses refer to oxide or metal additions, however.

Cerium fluoride additions are said to be effective in improving hot workability of austenitic steels only when the latter contain titanium.[10] It is supposed that the cerium fluoride fluxes away the complex titanium-chromium oxides formed in these steels, which normally tend to be trapped by the growing crystals during solidification.[10] If, indeed, this is the case, it is possible that fluorides other than cerium could cause this fluxing action, and the effect may then be said to be unrelated to the influence of rare-earth elements.

Influence of Rare-Earth Additions

Perhaps the best known use of rare-earth metals is in the manufacture of lighter flints, which consist essentially of a cerium-iron alloy. Apart from this application, rare earths have been successfully used for the last 25 years for a variety of other purposes, notable among which is their addition to the 80 : 20 nickel-chromium alloy used for electrical heating elements, the addition resulting in an extended service life.[14]

More recently, in the ferrous industry, rare earths have been instrumental in the successful development of spheroidal graphite cast iron. While a rare-earth addition alone will, under certain circumstances, produce spheroidal graphite structures in cast iron, magnesium is more effective and is now generally used. However, certain elements, such as lead, tin, bismuth and others, can interfere with the action of magnesium, and it has been shown that small additions of rare earths are capable of neutralising the harmful effects of these elements.[15]

Attention is now being given, particularly in the United States, to the addition of rare earths to steels. It is apparent from the literature that addition of the rare-earth oxides for the purpose of improving hot workability has received most attention. Only two reported investigations have dealt with the addition of rare-earth metals to cast steels, and the data from these form the major part of this section. It is, therefore, pointed out that in the following, the term "rare earths" refers specifically to the metallic form, and not the oxide, unless otherwise stated.

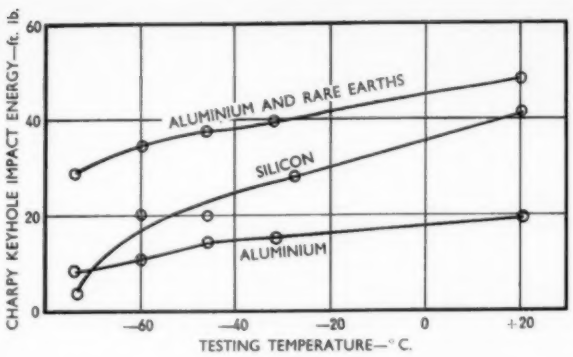


Fig. 1.—Improvement of low temperature impact properties of a 0·25% carbon steel by rare-earth additions.[5]

Mechanical Properties

Investigations have shown that the ductility and notch toughness of cast steels can be substantially improved by the addition of rare earths during steelmaking. Lillieqvist and Mickelson[4] found that improvements occurred with carbon and 1½% manganese steels, both in the normalised, and in the quenched and tempered conditions. The greatest improvements were exhibited, however, after quenching and tempering, irrespective of the tempered hardness. From this work, they conclude that the low temperature impact properties, in particular, are improved. However, examination of their data reveals that a comparatively small number of impact tests and sub-zero temperatures were employed, making this conclusion in itself of limited value.

A similar improvement in low temperature impact properties and ductility has, however, been observed by Berry and Dorvel.[5] These investigators tempered their steels after normalising, and also used larger rare-earth additions than Lillieqvist and Mickelson. Berry and Dorvel have also demonstrated that low temperature impact properties are better after deoxidising with aluminium and *mischmetall*, than when either silicon or aluminium is used alone. Curves showing their results are reproduced in Fig. 1, and data from the two researches are summarised in Table III.

Another aspect studied by Lillieqvist and Mickelson was the effect of rare earths on temper brittleness, or the deterioration in impact strength and ductility exhibited by certain steels when tempered in, or slowly cooled through, a critical temperature range. They observed the incidence of this phenomenon on a susceptible 1½% manganese steel which had been rare-earth treated, and concluded that rare earths do not eliminate temper brittleness. Nevertheless, their results show that, for steels in the temper brittle condition, the impact strength and ductility of the treated steels remain superior.

It is considered most likely that a factor contributing to the improved mechanical properties of cast steels, is the effect of rare earths on the sulphide phase, which results in globular, random sulphides appearing in the

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* *Mischmetall* at present costs approximately £1 to £1 8s. per pound, while rare-earth oxide mixtures cost approximately one-third of this amount.

† Rare-earth oxide mixtures are sold in this country and in the United States under the proprietary name RareMeT Compound.

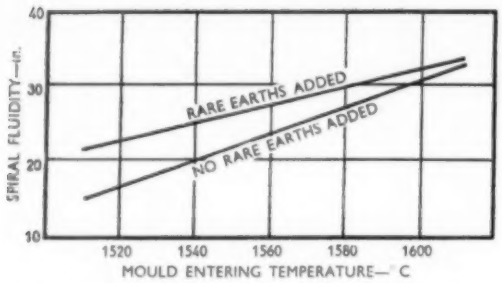

Fig. 2.—Improvement in fluidity of a 1½% manganese steel by rare-earth additions.[4]

solid steel. In cases where sulphur removal occurs, an improvement in properties may be anticipated, although this would not be expected to improve low temperature impact, since sulphur affects the maximum impact value in the fully tough condition, rather than the temperature of transition from tough to brittle fracture.

In this connection, the reported ability of rare earths to remove oxygen and nitrogen may be of importance, for both these elements raise the transition temperature of a steel. The same argument would apply if the rare earths were found to remove certain trace elements such as antimony and arsenic, because the latter also raise the transition temperature.

Other benefits might accrue from the removal of gases. Microporosity might be reduced to the point of elimination, with a consequent improvement in mechanical properties, and removal of nitrogen might render certain steels free from the susceptibility of failing by intergranular fracture, an occurrence generally attributed to the formation of aluminium nitride.

In the case of wrought steels, it is reported that rare-earth additions improve impact properties in the longitudinal direction only, and not in the transverse direction.[16] Improvements in ductility or notch toughness have not been generally obtained in wrought stainless steels, but rare earths have improved their stress-rupture properties in creep tests.[2]

Fluidity and Soundness

Limited experiments by Lillieqvist and Mickelson[4] have shown that rare earths can increase the fluidity of a 1½% manganese steel. For their experiments they used a double spiral test casting, taking the spiral length as a measure of fluidity. Their results are shown in Fig. 2, from which the improvement effected by rare earths is indicated. However, experimental points on the curves are not given, and, contrary to the findings of other investigators,[17] the relationship between spiral length and temperature is represented by straight lines. In consequence, it is difficult to assess the significance of these results.

The same investigators, on the basis of two cooling curves, claim that a rare-earth-treated 1½% manganese steel has a lower final solidification temperature than a similar untreated steel, by approximately 11° C., and conclude that this possibly contributes toward the improved fluidity and feedability of rare-earth-treated steels. However, it is not easy to understand how the alloying effect of a small addition (0·09%) of rare-earth elements could result in such a change in solidification temperature, and, furthermore, it is generally agreed that to measure this temperature by means of cooling curves is difficult. The change points on the curves drawn by Lillieqvist and Mickelson are certainly ill-defined. No mention is made of the change in the width of the freezing range, a factor which would be expected to influence feedability.

However, these investigators have carried out limited experiments on feedability, using test castings of the type developed by the U.S. Naval Research Laboratory, and again concluded that treatment by rare earths improves feedability. If this conclusion is correct, and if in fact rare earths do remove hydrogen and nitrogen

TABLE III.—EFFECT OF RARE-EARTH ADDITIONS ON THE MECHANICAL PROPERTIES OF ALUMINIUM-DEOXIDISED STEEL

Heat Treatment	Composition (%)					Rare Earth Addition	Tensile Properties				Charpy V-Notch (ft.-lb.)				Source
	C	Mn	Si	S	P		Y.P. (tons/sq. in.)	U.T.S. (tons/sq. in.)	El. on 2in.(l=4d) (%)	R.A. (%)	Room Temperature	−40° C.	−46° C.	−74° C.	
Normalised	0·26	0·70	0·45	0·032	0·015	No	20·2	33·9	30·4	52·7	35·9	11·8	—	—	(4)
						Yes *	20·5	34·0	30·6	56·3	48·0	15·8	—	—	
	0·43	0·70	0·45	0·032	0·015	No	24·9	41·8	24·1	37·8	19·5	7·8	—	—	
						Yes *	25·9	42·0	25·4	45·4	23·4	9·4	—	—	
	0·30	1·00	0·45	0·032	0·015	No	28·5	41·6	27·9	55·3	46·8	18·1	—	—	
						Yes *	28·6	42·6	28·9	60·6	52·5	23·1	—	—	
Normalised and Tempered	0·18	0·54	0·32	0·032	0·017	No	19·3	29·6	28·5	48·4	23·5 †	—	9·3 †	7·1 †	(5)
						Yes ‡	19·2	29·5	33·0	62·6	45·7 †	—	27·7 †	10·1 †	
	0·24	0·67	0·29	0·039	0·026	No	18·6	32·9	27·0	39·7	19·0	—	14·0	8·0	
						Yes ‡	18·2	32·9	31·0	62·1	50·0	—	37·0	28·0	
	0·32	0·62	0·43	0·039	0·022	No	19·0	33·0	26·0	45·5	—	—	—	—	
						Yes ‡	20·3	40·0	32·5	65·0	—	—	—	—	
	0·185	0·50	0·38	0·034	0·022	No	19·2	30·3	27·0	43·4	—	—	—	—	
						Yes ‡	19·3	29·1	32·5	65·8	—	—	—	—	
Quenched and Tempered	0·26	0·70	0·45	0·032	0·015	No	36·3	46·8	18·3	46·5	33·3	25·7	—	—	(4)
						Yes *	36·2	46·3	20·2	50·8	42·5	34·7	—	—	
	0·30	1·60	0·45	0·032	0·015	No	52·6	56·5	16·2	38·2	27·8	23·8	—	—	
						Yes *	52·4	56·1	18·2	47·1	42·5	34·8	—	—	
	0·43	0·70	0·45	0·032	0·015	No	61·0	69·0	11·5	30·5	17·0	16·0	—	—	
						Yes *	62·8	70·6	13·2	44·6	27·8	23·7	—	—	
	0·27	0·90	0·45	0·031	0·018	No	—	—	—	—	45·0 §	39·2 §	—	—	(5)
						Yes ‡	—	—	—	—	60·8 §	54·7 §	—	—	

* 2 lb. per ton metallic rare earths.
‡ 4 lb. per ton *mischmetall*.
† Charpy keyhole notch, average of three quoted results.
§ Average of three quoted results.

by their affinity for these gases,[13] then the addition of rare earths does contribute to making a sound casting.

Hot Tearing

The influence of rare earths on the susceptibility of a steel to hot tearing has also been investigated by Lillieqvist and Mickelson,[4] who used the A.S.F. standard hot tear casting as the basis of their experiments. Rare-earth-treated and untreated carbon steels were used, and the castings were pickled in hot hydrochloric acid before assessing the hot tear severity. Their results are reported graphically, and are reproduced in Fig. 3. Individual hot tear ratings are not given, but the curves serve to illustrate what improvements may be expected. Thus, at pouring temperatures of 1,570°–1,600° C., the susceptibility to hot tearing is a maximum, but is decreased to a marked extent by the addition of rare earths.

It is probable that the benefits derived from the rare-earth additions are due primarily to the change in inclusions from Type III to Type I, as reported by Lillieqvist and Mickelson. Furthermore, if the removal of sulphur, as reported by the same investigators, does in fact occur, this may also be a contributory factor in reducing hot tear susceptibility.

In this connection it is interesting to note that Middleton and Protheroe[18] have shown that both sulphur content and inclusion form are factors which influence the susceptibility of a steel to hot tearing.

Heat and Corrosion Resistance

At temperatures in the neighbourhood of 500° C., carbon steel oxidises fairly rapidly, and at temperatures above this, alloy steels become necessary for effective resistance to scaling. Little information is available on the effect that rare-earth additions have on scaling, but limited work by Beaver[2] has shown that rare-earth metal or oxide additions to a type 310 stainless steel (25% chromium, 20% nickel) increase its scaling resistance at temperatures ranging from 870° C. to approximately 1,050° C. However, this effect is reversed at higher temperatures, and above 1,100° C., the steel with rare-earth metal addition showed a marked increase in scaling rate. Similar effects were noted on other alloy steels, but were not quite so pronounced. The reason for such reversals is not understood. Another report in the literature[19] does, however, corroborate that rare earths can increase the scaling resistance of certain steels.

Beaver[2] has also reported on the corrosion resistance of stainless steels, containing rare earths. Neither metal nor oxide additions were found to have any significant effect on the corrosion rate of several stainless steels.

Hardenability and Weldability

In their comprehensive investigation of rare earths, Lillieqvist and Mickelson[4] conducted experiments to determine the effect of the additions on hardenability and weldability. Jominy end-quench tests on treated and untreated 1½% manganese steels showed the hardenability of the two steels to be virtually the same. Experiments were extended to include other medium and low alloy steels, but there was no increase in hardenability as a result of the addition of rare earths. Other work on wrought medium alloy steels in the slack-quenched and tempered condition, has confirmed that rare-earth additions have little or no effect on hardenability. It may be said, therefore, that these results

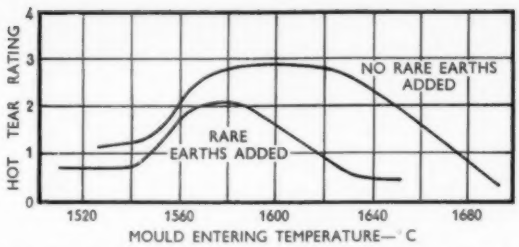

Fig. 3.—Reduction in susceptibility to hot tearing of a 0·26% carbon steel with rare-earth additions.[4]

infer that the improvement in low temperature impact properties is not associated with increased hardenability.

As a result of their investigations on weldability, these authors conclude that rare-earth treatment has no significant influence on this property in the case of medium alloy steels.

Method of Rare Earth Addition

In view of the highly reactive nature of the rare-earth metals, it is clearly of importance that any addition to steel should be made at the optimum time in the steelmaking procedure, to minimise loss and ineffectiveness. Since steelmaking practice varies to a great extent, it would appear that the most effective method of making rare-earth additions depends largely on the finishing practice adopted.

Before commencing their programme of research, Lillieqvist and Mickelson[4] examined the effect of adding 2 lb. per ton of a proprietary rare-earth metal, at various points in the finishing process. They made five variations by adding the rare earth (*i*) to the charge ; (*ii*) at melt-down ; (*iii*) after the ferro-silicon but before the aluminium and calcium-manganese-silicon additions ; (*iv*) after the aluminium but before the calcium-manganese-silicon ; and (*v*) after the calcium-manganese-silicon. Method (*iv*) was finally adopted, and the quantities per ton of charge used for basic open-hearth heats were 2 lb. of aluminium, 2 lb. of rare-earth metal, and 3 lb. of calcium-manganese-silicon. These were added after the normal additions of ferro-silicon and ferro-manganese.

When rare-earth additions were made to the charge, or to the bath at melt-down, little benefit was obtained, which indicated considerable loss by oxidation. A permissible deduction from this is that virtually no build-up of rare earths may be expected to result from the remelting of process scrap.

The literature suggests that rare-earth mixtures have generally been added to the ladle, either directly, or by introduction to the pouring stream.[2, 4, 21] For example, one investigator wired the rare earth to a bar of steel, which was thrown into the ladle at a point where the metal stream met the surface of that already in the ladle ;[4] alternatively, the rare earth has been placed in a weighted drum and thrown into the ladle as it filled.[22] One reported exception to this practice arose in the casting of ingots, when the rare earth was successfully added to the mould after pouring.[9]

Most investigators[4, 11, 19, 21] found 2–3 lb. of *mischmetall* per ton to be satisfactory in addition to the normal deoxidants. However, quantities up to 12 lb. per ton have been used for furnace additions.[11] For cast carbon and low alloy steels, *mischmetall* has been most effectively used, [4, 5, 9] and also for wrought medium alloy steels.[16] The extent of rare earth recovery in the steel is not clear

from the literature, as final analyses are hardly ever quoted.

Conclusion

While rare earths have been more widely acclaimed in the wrought austenitic steel field, as a means of improving hot workability and ingot yields, comparatively little attention has been given to their application in cast steels. Their potential use in metallic form has, however, been recognised, but only two researches dealing specifically with cast steels have been reported in the literature. In both cases, the work was confined to a comparatively small number of carbon and low alloy steels. The following conclusions are, therefore, based on restricted data, which consequently limits their value.

Rare-earth metal (*mischmetall*) additions :—

(*i*) improve ductility and impact properties : they do not prevent the occurrence of temper brittleness in a susceptible steel ;

(*ii*) reduce susceptibility to hot tearing, and improve fluidity ;

(*iii*) do not affect hardenability or weldability ;

(*iv*) can be made most satisfactorily to the ladle, in quantities ranging from 2–4 lb. per ton of steel.

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A Preliminary Study of the Fatigue of Metals in Liquid Metal Environments

(*Continued from page* 232)

Even when the system is such that chemical attack is known to take place, the effect on endurance strength may not be a major one at stresses in the region of the fatigue limit. It is obvious, however, that this can only be the case when the extent of the chemical attack is comparatively small.

From a technological point of view, when liquid metals are to be used under conditions in which corrosion fatigue is possible, it may be that, provided the stresses in the system are kept below the normal fatigue limit with customary safety factors, premature failure will not take place due to the liquid metal. Much more work is needed, however, before a general pattern of behaviour can be formulated.

Acknowledgments

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Appendix

Analysis of Materials

Copper Alloys

	Cu %	Zn %	Fe %	Mn %	Ni %	P %	Pb %	Sn %	Cd %	S %	Cr %
70/30 Brass for Wobler Tests	71·3	Balance	0·05	<0·01	<0·01	Tr	<0·1	Tr	—	—	—
60/40 Brass for Wobler Tests	57·6	Balance	0·14	<0·01	0·11	Tr	2·70	0·42	—	—	—
Copper/Tin Alloy Wire	98·2	0·29	<0·01	<0·01	—	0·009	<0·1	0·96	—	<0·002	—
Copper/Cadmium Alloy Wire	99·1	—	0·01	<0·01	—	Tr	<0·1	Tr	Balance	<0·002	—
70/30 Brass Wire	70·1	Balance	0·02	<0·01	<0·01	Tr	<0·1	Tr	—	—	<0·02

Steels

	C %	Si %	Mn %	P %	S %	Ni %	Cr %	Ti %
Free-cutting Mild Steel	0·115	0·02	1·06	0·059	0·289	—	—	—
Stainless Steel	0·045	—	—	—	—	8·40	18·13	0·43

Bicentenary of a Brilliant Metallurgist

D'Elhuyar's Work on Tungsten and Platinum

By M. Schofield, M.A., B.Sc., F.R.I.C.

Among the promising young men sponsored by Charles III of Spain in readiness for the development of mining and metallurgy in the Spanish colonies in South America were the D'Elhuyar brothers. The first-class training they received in such institutions as the Royal School of Mines at Freiberg, combined with their practical experience, enabled them to make important contributions to the metallurgy of tungsten and platinum. This year is the two hundredth anniversary of the birth of Don Fausto D'Elhuyar.

IN the history of mining and metallurgy there are few chapters of greater interest than those concerned with Spain or the one-time Spanish colonies in South America. Particularly is this so when tungsten comes into the story, when there came the discovery of "Wolfram," the "wolf metal that eats up tin as a wolf eats up sheep" as our Cornish miners long lamented before British supplies came from the little parishes of Wheal Harmony and Wheal Friendship, as well as from Castle-an-Dinas and wild Skiddaw. The anniversary of the birth 200 years ago of Don Fausto D'Elhuyar (or De Elhuyar) is a reminder of this absorbing history. Both Don Fausto and his brother were metallurgists granted full backing or sponsorship by a Spanish monarch who sent these brilliant young men to the best schools of the day that Europe could offer. One need only say that one of these institutions was the Royal School of Mines at Freiberg, a centre which turned out such famous men as Del Rio, discoverer of vanadium. Don Juan José D'Elhuyar also put in a period under the eminent Swedish mineralogist Bergman, the master who trained students like Gahn, discoverer of manganese, and Hjelm, discoverer of molybdenum. This first-class training in European schools, together with the D'Elhuyar brothers' practical experience in charge of mining in South America, all contributed to the advance of metallurgy, and of tungsten and malleable platinum in particular.

Foreign Studies

After the two brothers had proved exceptional students in Spain, Don Fausto went first to Paris in the move to study abroad. In 1778 the two D'Elhuyars arrived at the Freiberg School of Mines, where Clemens Winkler, discoverer of germanium, had become professor five years previously, and where the mineralogist Werner was to teach his notable theory of vein formation. The two brothers were fortunate in that the Spanish government was in the mood for fully sponsoring promising metallurgists and chemists in readiness for the development of mining and metallurgy in the Spanish Empire in South America. It was a period in which Charles III of Spain was to set up the finest chemical laboratory in the world at Madrid; one so lavishly equipped that at one period there was brought in more platinum than the rest of the world could total. Apart from there being this "platinum age" in Spain, in which Don Fausto collaborated with Chabaneau in rendering the obdurate metal malleable, there were other rich harvests from South America to be gathered. It was no wonder, then, that royal backing of the best students was so readily forthcoming with an eye to the future. The brother Don Juan José (whom one hesitates to call simply Don Juan !) came under the influence of Torbern Bergman at Upsala, an important point, since Bergman comes into the tungsten story. Bergman had analysed scheelite and found an acidic oxide, later to be named tungstic acid, which he hoped others would take up and study more fully.

One can hardly over-estimate the value of the next stage in the career of an eminent metallurgist-to-be. Back in Spain, there had been founded in 1777 the famous Seminary of Vergara, just four years before Don Fausto arrived to take up his lecture duties at the college. It was here that tungsten was to be discovered in the historic analysis of wolframite, which yielded in turn the first crude tungsten metal. Here had come such first-rate teachers as Joseph Louis Proust, that chemist who, alas, seems known only for his discovery of the Law of Definite Proportions, and hardly at all for his part in rendering platinum malleable well before Wollaston began a second period of platinum history, a second example of a process kept "secret" for so long. The Frenchman Proust had an equally versatile countryman, Francois Chabaneau, to work with him and with D'Elhuyar in platinum metallurgy—this before King Charles III stepped in and made Chabaneau Professor of Mineralogy and Chemistry at Madrid. It was Chabaneau who had at his disposal more platinum than had been available anywhere else, with 46 kg. crude platina and 18½ kg. of purified metal sent to the Royal Madrid Laboratory, where even beakers were of platinum.

The Discovery of Tungsten

Before his arrival at Vergara, Don Fausto had already published practical studies on copper mines, on the manufacture of tinplate, and on iron smelting. The two brothers came into possession of some wolframite from a Zinnwald tin mine, and from it they prepared their "wolframic acid," which was to be shown to be the same as the tungstic acid prepared by Scheele in 1781. Scheele had decomposed "heavy stone" (now known as scheelite) with nitric acid, and had found it to yield a white acidic oxide, rather like molybdic acid in general characteristics. Johann Lehmann of St. Petersburg is mentioned in history as having first analysed wolframite; but this point matters little since Lehmann, as in the case of analysing chromium ores, discovered nothing of importance. It was from wolframite, or *lupi spuma*, and not scheelite that the first sample of tungsten metal was prepared. The D'Elhuyars as metallurgists did more than establish definitely that a new element was present, one suspected by others like Peter Woulfe, who, in the

Philosophical Transactions in 1779, hinted at such a possibility. The two brothers mixed tungstic acid with ground charcoal and heated the mixture strongly in a luted crucible, and obtained a crumbly button or layer of residue. This contained particles of metallic tungsten, the wolf metal that proved so intractable until powder metallurgy brought the answer. The D'Elhuyar brothers then told how tungsten had no applications or uses apparent to them, but no doubt the future would alter this. Their work on tungsten is aptly summarised in Cullen's translation of their paper, a translation appearing in 1785: "A Chemical Analysis of Wolfram and the Examination of a New Metal which enters into its Composition." This was published in London, had a preface by Bergman, and was followed a year later by a German translation.

Platinum Metallurgy

The following year proved an important one in Don Fausto's career for two reasons. Not only was he sent to study mining and extraction processes in Hungary and Germany, prior to being appointed director-general of the royal mines in Mexico; but he also collaborated in that year with Francois Chabaneau in some remarkable studies of platinum. This latter point is evident from letters written to his brother Don Juan José, who was in Colombia at the time. Chabaneau, like his countryman Proust, had held a poorly-paid post in France before being invited to become a colleague of the D'Elhuyars at the Vergara academy. He was to become the leader in the Spanish school of platinum metallurgy, in a period in which malleable platinum was produced in quantity. What is remarkable about this malleable platinum chapter is that any success at all in producing a malleable metal was possible before Smithson Tennant and others discovered other platinum metals in crude "platina." It must have been by luck and persistence that Chabaneau and the D'Elhuyars made a platinum sponge and compressed it to a malleable ingot while still at a high temperature, especially since iridium present at times embrittled the platinum. The Spanish platinum era had begun when Don Antonio De Ulloa, member of a Spanish expedition to South America, had reported seeing water-worn nuggets of a silver-white metal fished out of the River Pinto by natives, and used in fashioning rough ornaments, and possibly by their children in games like pitch and toss. The metal was to be called "little silver," which South American colonies of Spain provided in such quantities for Chabaneau that on one occasion he fashioned a ten-centimetre cube weighing 23 kg., a most remarkable ingot of platinum which a visitor to the laboratory attempted to pick up and then accused Chabaneau of having jokingly fastened it to the bench. Chabaneau's platinum, with inclusions of other platinum metals, gave such variable results at times that the Frenchman almost despaired of succeeding in standardising the process. "Away with it all. I'll smash the whole business. You'll never again get me to touch the damned metal!" Such was his bitter cry when the Marquess of Aranda arrived at the laboratory one day to find Chabaneau throwing out of the window his platinum residues. Yet Chabaneau succeeded to such an extent that he was able to supply ingots of malleable platinum to the goldsmith Jeanety of Paris. In 1784, Achard, noted for his work on beet-sugar, made the first platinum crucible in using the common method of rendering platinum malleable in his day, viz., by alloying with arsenic to lower the softening-point and volatilizing the arsenic. But Jeanety was the first to supply the laboratories of Europe, including London, with platinum crucibles, though these were expensive. How much the D'Elhuyars contributed to Chabaneau's success we shall never be certain, though the partnership between metallurgists and chemist was certainly fruitful.

That King Charles III of Spain was an enthusiastic patron of technical developments of his country's resources is shown not only by his active interest in platinum, but in opening up mines in South America. Don Juan José D'Elhuyar was sent by the king to Colombia, while in 1788 Don Fausto was called upon to go to Mexico City to direct the royal mines of Mexico. Within four years time, a school of mines had been established, with Don Fausto the inspired director, with his improved technique introduced into mining and his studies of the cold amalgamation process for extracting silver. D'Elhuyar published important papers on mining in "New Spain," on coining at the Mexican Mint, and on similar subjects. Only in 1821, after more than 30 years work rendering invaluable service in the cause of Spanish metallurgy, was D'Elhuyar able to return to Madrid, where he founded a mining engineering school to improve the home mining industry in his last years.

Large Cast Iron Cutting Operation

WHEN a winding engine drum had to be removed recently after becoming obsolete at Cwm Colliery, Llantwit Fardre, South Wales, the demolition contractors engaged to carry out the work called upon British Oxygen Gases, Ltd., for assistance.

Weighing 107 tons, the drum was made of cast iron which ranged from 2½ in. to 8 in. in thickness: It was 20 ft. high and 20 in. wide. The contractors, Messrs. R. S. Hayes, Ltd., of Bridgend, were informed by the N.C.B. that the work had to be completed within 36 hours, in order to prevent heavy loss of production at the colliery.

British Oxygen's Cutogen No. 6 powder cutting blowpipes were used to sever the drum into 12-ton sections, which were then transported from the site by lorry. Each team of men was duplicated so that there would be no stoppages, either for meals or for any other reason. The work took only 29 hours to complete, after which a new drum was fixed in place, and the work of the colliery was able to be carried on without delay.

Continuous Production of Dustbins

A NEW continuous production line for manufacturing dustbins has been installed in the Shipley, Yorkshire, works of W. P. Butterfield, Ltd. The system includes automatic washing, spraying with flux, drying and galvanising, and is capable of processing 200 dustbins each hour. For the washing-off process, the dustbins are sprayed with jets of water supplied by an M50 pump provided by Megator Pumps and Compressors, Ltd. A similar pump also sprays the dustbins with a mixture of zinc chloride, powdered ammonium chloride and water, in the flux spraying process. Both the Megator pumps are cast-iron with stainless steel rotors, running at 630 r.p.m.

Foundry Services' Open Day

New Factory and Research Facilities on View

Modern office accommodation at the new factory.

A GOOD deal has been heard recently about after-sales service, and there is little doubt that it is an important factor in the struggle for export markets, particularly in the automobile field. In most cases, such activities, necessary though they may be, are regarded as ancillary to the main business of the firm, and it is rather unusual to find a concern where service is the foundation on which the manufacturing activities are built. Such firms do exist, however, and an outstanding example is provided by Foundry Services, Ltd., which this year celebrates its silver jubilee.

Scope of the Company's Activities

The manufacturing side of the company produces a standard range of over 200 chemical preparations—the Foseco compounds—prescribed in accurate " doses " to assist foundrymen in producing perfect castings. This is backed up by a service of diagnosis of casting defects, which operates in conjunction with a technical staff working in up-to-date laboratories at the Birmingham headquarters. No charge is made to customers for this facility ; the foundry concerned merely sends a sample of the imperfect casting, together with a note on the foundry routine. Exhaustive tests follow in the laboratories, development foundry and related departments, and, in due course, the customer receives a full report on the defect and the remedial measures advised.

In most cases a report is issued in four days, and as many as 80 investigations may be in hand at one time. Last year the Nechells laboratories dealt with, and advised on, 2,500 such samples. In some instances the investigations are on a much larger scale, as for example in the case of a non-ferrous foundry where melting losses were reduced from more than 10% to a figure of 3–4%. This followed a 10-day investigation in the foundry, with three metallurgists working round the clock.

The link between the company and its customers is strengthened by the maintenance of a team of experienced technical representatives who pay frequent visits to foundries in all parts of the country : a similar team covers the overseas customers. This liaison work is an important function of these teams, as it not only helps the foundries to take advantage of existing Foseco preparations, but it also discloses problems which might usefully form the subject of investigation at Nechells.

Since its formation, the company has undertaken the production of technical literature in simple language with the object of educating the foundry worker. In the management's view there is far too little instructive material directed at the man on the shop floor. Foundry Services has produced, and continues to produce, a vast amount of literature, including a regular journal called *Foseco Foundry Practice*, which is practical, clear and written in terms that the foundryman will understand : it has a circulation of 26,000. Other publications include information sheets and charts, and the Foseco " Foundryman's Handbook." Many of the publications are available in Dutch, French, German, Japanese, Spanish and Swedish.

A Story of Steady Progress

Foundry Services, Ltd., came into being through the enterprise of two young scientists, Mr. Eric Weiss and Dr. K. Strauss, who had for a long time been preoccupied with the technical difficulties standing in the way of producing perfect castings. They came to the conclusion that a project combining technical research with the production of special chemical preparations could serve foundries working in every class of metal, and in 1931 they set up in a small way to provide those facilities. A small office and a warehouse were rented in Birmingham, and for a time Dr. Strauss divided his time between university teaching and Foundry Services, Ltd. Progress was rapid, and little more than a year after its formation the company was forced to seek larger premises, and Dr. Strauss to devote the whole of his time to the business.

Accommodation was found in premises in the Nechells district of Birmingham, which the company still occupies, and the whole of its activities were carried on there for a number of years. During this period, increased floor space was provided by the acquisition of adjoining premises, some of which were, unfortunately, destroyed by bombing during the war. In order to carry out Government contracts, the company looked around for a new factory, and found a disused timber yard at Drayton Manor, Tamworth. The Ministry of Aircraft Production took over the site, built a factory on it and rented it to the company. After the war, production continued at Tamworth and a new factory has now been built there, to which all manufacturing departments have been transferred. The Nechells premises remain the

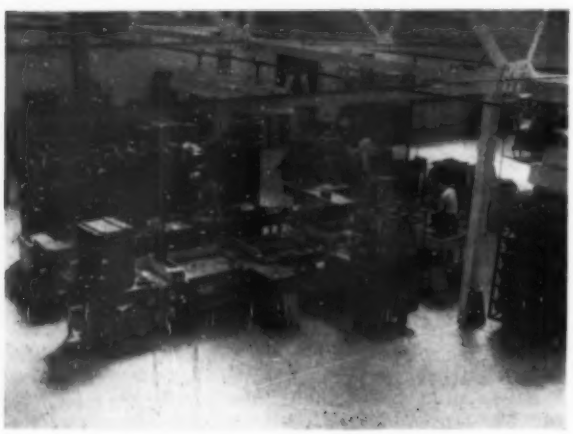
High speed mixing machines.

headquarters of the company and, in addition to administrative and sales staff, house the development, research and service departments.

The foundry industry is one in which the skill of the operative can have a considerable influence on the quality of the product, particularly in non-repetition work, and although there has been a great improvement in this respect in recent years, there was a time when a scientific approach to foundry problems was looked upon with some suspicion. One of the main tasks facing the new enterprise a quarter of a century ago was to break down the traditional conservatism in the industry, and after a difficult start it speaks well of the success of the efforts to do so that the list of customers in the United Kingdom alone contains almost 4,000 names, with annual sales of 15,000–20,000 tons of Foseco preparations. If the founders would want to seek further justification for their original inspiration, they must surely have found it in the growing enquiries from foundries overseas which have led to the establishment of associate manufacturing companies in Austria, Canada, France, Germany, Italy, South Africa and the United States, and of agencies in 40 other countries throughout the world.

Research, Development and Service Laboratories

As a result of the transfer of the production departments to Tamworth, space became available for a new research laboratory and foundry at Nechells, where long term development work is at present being carried out in a number of important fields. On the occasion of the recent "Customers' Open Week," visitors were able to inspect the facilities available for this work, and to see, by means of typical examples, the way in which the benefits of recent scientific developments are brought to bear on any problem.



The Feedex sleeve production shop.

The foundry is equipped with small furnaces for melting a wide range of metals under conditions similar to those prevailing in production foundries. They include an indirect arc furnace capable of melting 15–20 lb. of steel, a gas-fired reverberatory furnace, and crucible furnaces of the tilting, lift-out and bale-out types. This equipment is used in the development of the covering and protecting fluxes, degassing compounds, and alloying additions which form a large proportion of the 200 Foseco preparations. In order to assess the efficiency of degassing compounds, equipment has been developed for quantitatively estimating the gas content of light alloy melts, by allowing a sample to cool and solidify under vacuum.

An interesting development in the alloying field is the production of Foseco Navac—a vacuum-processed metallic sodium, sealed in airtight containers and free from oil, oxides and other gas producing elements. By the use of this material in the modification of aluminium-silicon alloys, gas pick-up during modification is avoided, and the full benefit of the preliminary degassing is obtained. Furthermore, crucible attack associated with modifying salts is eliminated.

For the study of iron melting, a small experimental cupola is available which has a 10 lb. well capacity and a melting rate of 1 cwt. per hour. This can be used in investigations on the desulphurising and dephosphorising of iron, in the development of Cupolloy additions of alloying elements in briquette form, and in assessing the relative merits of various linings.

Work is at present in progress on a number of melting problems, including the fluxing and deoxidising of high conductivity copper, the grain refinement of aluminium alloys, and the development of self-sinking degassing compounds to eliminate the need for plunging them to the bottom of the melt.

Besides additions to the metal during or after melting, Foseco preparations include a range of coatings for moulds cores and dies, and materials for use in some of the more specialised moulding processes. Examples of the latter include the Pattrit casting plasters, specially prepared for the production of aluminium matchplates by either gravity or pressure casting, and Investite, an investment moulding for use in precision casting which incorporates its own binder.

An intensive investigation into the CO_2 process of coremaking and moulding has resulted in the formulation of CO_2 Set, which is used for bonding instead of sodium silicate. It is free flowing, non-toxic and non-fuming, and it produces moulds and cores giving excellent finish and good collapsibility.

The range of exothermic compounds marketed under the general title of Feedex constitutes one of the most important of Foundry Services' developments. Feedex incorporates a binder which enables it, when mixed with water, to be moulded into suitable shapes. The shape of widest application is that of a hollow cylinder or sleeve, which is inserted into and made to line the inside of feeding heads in moulds. The Feedex is ignited by

the incoming metal as it enters the head, and the exothermic action maintains, and may even increase, the temperature of the metal in the head, so that feeding is much more effective. Even when the reaction is finished, the superior insulating properties of the sleeve, as compared with moulding sand, considerably reduce heat loss by conduction. By the use of Feedex sleeves, sound castings can be produced with much less waste of metal in feeder heads. Apart from their use in feeding, Feedex shapes can be used at any position in the mould to assist directional solidification by acting as negative chills.

Sand moulds do not constitute the sole application of these compounds, as Feedex linings have been used in the " hot tops " of ingot moulds in the steel industry, and increases in yield of as much as 10% have been attained at an approximate cost of 10s. per ton of ingot. Economies have been effected by using Feedex linings with an insulating backing, thus reducing the amount of compound needed.

The essential difference between grades is in their reaction time, and the selection of the appropriate grade is governed by such factors as : (*a*) pouring temperature of the alloy ; (*b*) freezing range of the alloy ; and (*c*) size of the head.

Research and development work in this field continues, and among aspects illustrated were the determination of the heat output of exothermic materials and the measurement of the thermal conductivity of exothermic and insulating materials by a recently developed technique, in which a heating element is inserted in an axial hole in a cylindrical compact and thermocouples are located at various distances from it.

Apart from the laboratories where long-term research projects are undertaken, there are chemical and metallurgical laboratories and a smaller foundry where short-term development work is undertaken, and where recommendations made to customers can be demonstrated in practice. In addition, all the company's representatives throughout the world receive part of their training in this foundry.

The extensive facilities in the chemical laboratory enable such techniques as flame photometry, absorptiometric analysis, electrometric analysis and polarographic analysis to be used in addition to the more conventional analytical methods. It will be appreciated that this laboratory deals with a very wide range of analytical problems covering slags, minerals and refractories, in addition to metals and alloys.

The metallurgical laboratory is fully equipped for microscopic and radiographic examinations, and plays an important part in all aspects of the company's activities, whether in research and development work or in the diagnosis of defects in customer's castings.

The New Factory

Although the constituents of the Feedex compound undergo considerable variation according to the kind of metal to be poured and the type of mould, aluminium powder and an oxidising agent are essential constituents. Since much of the finely divided aluminium used for this purpose is contaminated as received at the works, it is first subjected to vacuum distillation to remove oil, grease and water.

Automatic packeting machines and tableting presses.

Because of the composition variations referred to above, large stocks of different chemical metal powders have to be held. Particularly prone to flash is the finely divided aluminium powder, which necessitates stringent precautions during screening. This process and that of high-speed mixing of the general run of exothermic compounds is carried out behind blast-proof doors and walls. An ingenious locking system which connects the filling of the mixers with the " dispensers " on the upper floor has been designed not only to obviate fire risk, but also to ensure the highest degree of safety for all personnel engaged in these departments.

When mixing is complete, the compound may be packaged ready for sale, or it may passed to another department where Feedex shapes and sleeves are made. The compound is mixed with the appropriate amount of water and moulded by hand ramming, jolt ramming, or core-shooting : the last named method is largely replacing hand ramming. Drying is carried out in stoves at moderate temperatures, depending on the grade of Feedex. Finally, safety in transit is ensured by the use of elaborate wrappings and other protective devices.

Other Foseco preparations are manufactured in a separate mixing plant, where the dangers associated with the aluminium powder are absent. On the upper floor, the different constituents are weighed into a long battery

A section of the warehouse.

of hoppers, from which they are gravity-fed to the high-speed mixing machines below. This section is remarkably free from dust, considering the large quantities of finely-divided powders handled. A highly efficient system of dust extraction maintains a condition which is as necessary for cleanliness and chemical purity as it is vital for the health of the workers.

From the mixers, which are heated to ensure products free from moisture, the preparations pass to the packaging department, where some are made into tablets, others are briquetted and others again are automatically measured into packets. Certain products are supplied in copper tubes, and a section of the packaging department is equipped for the manufacture of these tubes from copper strip, and for their subsequent filling by automatic machine.

The extent of the Foseco range and the need to hold large stocks of the products for instant dispatch has resulted in the fullest possible use in the finished product warehouse of palleting in conjunction with the latest design of gallows fork trucks. A separate section is responsible for packing material for export, and a glance at the destinations marked on the packing cases gives an indication of the extent of this trade. The company deals on an important scale with some 48 countries and, as mentioned earlier, exports "know-how" to the countries in which manufacturing facilities have been established.

Massive Hammer Block Casting for Axle Forge

WHAT is believed to be the largest steel casting made for a forging hammer block in this country was recently installed in the axle forge at the works of Steel, Peech and Tozer, Rotherham, a branch of The United Steel Cos., Ltd. The £15,000 casting, which has a machined weight of 143 tons, was made at the Grimesthorpe steel foundry of English Steel Castings Corporation, Ltd., Sheffield, for B. & S. Massey, Ltd., Openshaw, Manchester, the builders of the 7-ton forging hammer.

The new hammer block, which is a one-piece steel casting, replaces an 82-ton two-piece block consisting of an upper section in steel and a lower section in iron, the two being dovetailed and keyed together. In service, it was found that the two sections of the block were beginning to work loose, causing a deterioration in the quality of the axles being forged, due to slight lateral and longitudinal movements of the block, which is independent of the hammer itself. In addition, maintenance costs were becoming excessive. As an absolutely stable base is essential for high quality forging, it was therefore decided to install the new and heavier single-piece block, giving a ratio of block to hammer of 20 : 1, compared with a ratio of 12 : 1 with the former block.

The delivery and installation of this massive casting called for careful advance planning and was arranged to coincide with the annual stop weeks at Steel, Peech and Tozer. Two days beforehand, the casting was loaded on to a Pickford's heavy trailer at English Steel Forge and Engineering Corporation's River Don works and transported for three miles to the Templeborough melting shop of Steel, Peech and Tozer, where a 150-ton overhead crane transferred it to a special railway wagon supplied by British Railways. The railway authorities had previously strengthened a bridge and rail tracks across the River Don so that the casting could be safely delivered to the axle forge building.

Production in the forge ceased at 1 p.m. on Friday for the annual holiday, and work began immediately on dismantling the forging hammer completely. The old block was removed, the new one placed in position and the entire hammer rebuilt by 10 p.m. on Sunday two weeks later, ready to resume operations on Monday morning when the production workers returned from holiday. It is interesting to note that this major replacement was carried out entirely by members of Steel, Peech and Tozer's staff, due to the strike of maintenance craftsmen which was then in progress.

Soon after resumption, it was apparent that the anticipated improvement in quality of the railway wheel axles was being achieved, and it is expected that higher output will result from the quicker reaction and better impact between hammer and anvil block.

Arc Furnaces Replace Open Hearths

IN connection with a reconstruction scheme being undertaken by Brymbo Steel Works, Ltd., near Wrexham (a subsidiary company of Guest Keen and Nettlefolds, Ltd.), three 16-ft. diameter, 40-ton Birlec Lectromelt arc furnaces have been ordered at a total cost exceeding £300,000. These furnaces are to replace the Company's existing open hearth plant. Each furnace will have a transformer capacity of 12,500 kVA., and will be arranged for top charging from buckets of capacity approximately equal to the available charging space in the furnace when using cold scrap charges. It is, however, intended to use 50% charges of pre-refined hot blast furnace metal in order to reduce the time and cost of melting, and to achieve maximum output from these furnaces.

NEWS AND ANNOUNCEMENTS

Sir Alfred Herbert Travelling Scholarship

To mark the occasion of Sir Alfred Herbert's 90th birthday, and in recognition of his outstanding service to the industry, the Machine Tool Trades Association has instituted a Scholarship to assist engineering students to add to their studies. This Scholarship, the annual value of which will be about £125, is to enable students of Coventry Technical College to widen their knowledge of machine tool design and manufacture, and of production methods, by visiting engineering works in the British Isles or on the Continent. The award will normally be made in the Autumn by Trustees and will include the presentation of a medal.

Candidates between the ages of 21 and 30 on July 31st, of the year of the award will in general be eligible. The minimum educational standard will be that corresponding to the requirements for Corporate Membership of the Institution of Production Engineers. In addition to full details of education and training, the candidate will be required to submit his own proposed programme for the tour. On completion of his tour the holder of the Scholarship will be expected to submit a report to the Trustees. The following have undertaken to serve as Trustees : Mr. B. C. Harrison (Director, Alfred Herbert, Ltd.), Mr. J. G. Petter (Director, Cincinnati Milling Machines, Ltd.), and Mr. S. J. Harley (Chairman and Managing Director, Coventry Gauge & Tool Co. Ltd.)

The Iron and Steel Institute

Autumn General Meeting

The Autumn General Meeting of The Iron and Steel Institute will be held at the Offices of the Institute, 4, Grosvenor Gardens, London, S.W.1, on Wednesday and Thursday, 21st and 22nd November, 1956. Details of the proceedings at the technical sessions will be as follows :—

Wednesday, 21st November.

11 a.m. to 1 p.m. Presentation and Joint Discussion of the following papers :—

Recording Techniques for Rolling Mill Operation Studies, by E. A. Chard, W. W. Hastings and D. F. Nettell (August, 1956*).

The Time Characteristics of the Slabbing Mill, by H. G. Jones, D. T. Steer and P. D. Dickerson (August, 1956).

Notes on the Principles Governing the Design of Ingots for High Output in the Slabbing Mill, by H. G. Jones, P. D. Dickerson and D. T. Steer (August, 1956).

Maximum Utilization and Problems of Wide-strip Rolling and Sheet Finishing Equipment, by H. H. Ascough (September, 1956).

2.15 p.m. to 3 p.m. Presentation and Discussion of the paper on :—

Automatic Stock-level Control on Blast Furnaces, by I. Kjellman and K. Gronblad (February, 1956).

3 p.m. to 3.45 p.m. Presentation and Discussion of the paper on :—

The Measurement of Gas Transit Times in a Blast Furnace, by T. W. Johnson (September, 1956).

3.45 p.m. to 4.45 p.m. Presentation and Discussion of the paper on :—

Studies of Blast Furnace Assessment, by J. M. Ridgion and A. M. Whitehouse (November, 1956).

Thursday, 22nd November.

10 a.m. to 11.15 a.m. Presentation and Joint Discussion of the following papers :—

The Enthalpy and Specific Heat of Iron and Steel. A Critical Survey of the Methods of Determination, by J. R. Pattison (August, 1955).

An Analysis of the Available Data on the Total Heat of Commercial Steels, by J. R. Pattison (May, 1956).

The Enthalpy of a 0·12% Carbon Steel, by J. R. Pattison and T. H. Lonsdale (July, 1956).

The Enthalpy of Pure Iron, by J. R. Pattison and P. W. Willows (August, 1956).

11.45 a.m. to 1 p.m. Presentation and Discussion of a paper on :—

The Study of 7% and 8% Chromium Creep-resisting Steels for Use in Steam Power Plant, by M. G. Gemmill, H. Hughes J. D. Murray, F. B. Pickering and K. W. Andrews (October, 1956).

2.15 p.m. to 4 p.m. Presentation and Joint Discussion of the following papers :—

The Tempering and Nitriding of some 3% Chromium Steels, by C. C. Hodgson and H. G. Baron (March, 1956).

Some Experiments on the Composition of Carbides in Low-alloy Steels, by J. R. Bowers (July, 1956).

Bainitic Retained Austenite, by J. A. Cameron (July, 1956).

The Temperature of Formation of Martensite and Bainite in Low-alloy Steels. Some Effects of Chemical Composition, by W. Stevens and A. G. Haynes (August, 1956).

The Tempering of Plain Carbon Steels, by E. D. Hyam, and J. Nutting (October, 1956).

An Electron Microscopic Examination of the Alloy Carbides Precipitated during the Fourth Stage of Tempering, by K. Kuo (November, 1956).

* The date in brackets after the title of a paper indicates when the paper was published in the *Journal of the Iron and Steel Institute*.

Spectroscopy Symposium

The Eighth Annual Symposium on Spectroscopy, organised by the American Association of Spectrographers, will be held at the Hotel La Salle, Chicago, next April. Papers are invited from spectrographers and workers in associated fields, abstracts of which should be submitted to Mr. Theodore H. Zink, Symposium Chairman, at H. Cohn & Sons, Inc., 4528, West Division Street, Chicago, Illinois, before January 1st, 1957. Authors should state whether a paper will be presented personally, or by someone nominated by the author, or whether it will be necessary for the Association to have available a person qualified in the author's field to read it.

New Title for Engineering Exhibition

The Engineering, Marine and Welding Exhibition has, over a period of fifty years, been recognised as the shop window of British engineering and allied trades. Known first as the Engineering and Machinery Exhibition, and thereafter for many years as the Shipping, Engineering and Machinery Exhibition, the title and subtitles have, from time to time, been modified to take account of natural developments in the engineering industry. Arising from British progress in nuclear power, it is fitting that this internationally famous show should display British achievements in the relatively new

engineering techniques required in the development of nuclear energy. In 1957 the Engineering, Marine, Welding and Nuclear Energy Exhibition will, as its new title suggests, focus world attention on British achievements in this field.

The organisers, F. W. Bridges and Sons, Ltd., can be justly proud of their past services to the engineering industry, and, at Olympia from 29th August to 12th September, 1957, a display worthy of its predecessors will mark the entry of the exhibition into its second half-century.

European and U.S. Titanium Experts Meet

On the 14th September, 1956, a meeting of European and American experts was held at O.E.E.C. Headquarters to exchange information on recent developments in the titanium industry. This meeting was organised by the members of the Technical Assistance Mission on "Titanium, Zirconium and Other Elements of Growing Industrial Importance" which went to the U.S.A. in Spring 1955, and which made provision at the outset for mutual exchange of information on questions of common interest and for contact between European and American experts. The Report of the Mission has been published recently by the O.E.E.C. in French and English. The 55 European experts present came from Austria, Belgium, France, Germany, Italy, Norway, Sweden, and the United Kingdom. The American experts were Mr. A. H. Robertson, from the Bureau of Mines in Albany, Oregon, and Mr. D. F. Dickey, from Firth Stirling Inc. in Pittsburgh.

The main subject of discussion was the melting and casting of titanium and the working and anti-corrosive properties of titanium alloys. Mr. A. H. Robertson showed a film on the latest technique evolved in the laboratory of the U.S. Bureau of Mines for melting and casting titanium, and supplied information on the details of these processes. Mr. Zwicker, of the Laboratory of Metallgesellschaft, Frankfurt, Germany, spoke on the binary system of titanium and aluminium, and on aluminium-containing alloys. The researches made by Société Péchiney, France, on the electrolytic coating of titanium and titanium alloys were introduced by Mr. R. Syre, and Mr. Rudiger, from the Laboratories of Friedr. Krupp, Essen, gave an exposé of his researches on the corrosion of titanium and the application of titanium in the chemical industry.

Blackman Export Co. Ltd.

At an Extraordinary General Meeting of the Blackman Export Co., Ltd., held on Tuesday, September 25th, Messrs. Keith Blackman, Ltd., acquired the majority shareholding giving them control of the Company. Upon the resignation of the existing board, the following Directors were appointed: Mr. D. S. Woodley (Chairman), Mr. A. L. Ayton (Secretary) and Mr. A. H. Woodley. Under the new management the Company will continue its normal activities from its present address at 23, Queen Square, Southampton Row, London, W.C.1.

Sheet Stockholding Scheme

The Steel Company of Wales has announced that, in order to improve sales service to sheet customers throughout the country, a scheme has been initiated under which four firms have accepted appointments as "Accredited Sheet Stockholding Merchants" to the Company. The main purpose of the scheme is to offer broad distribution of excess and defective sheet products throughout England and Wales, and to assist the buyer of smaller tonnages in obtaining supplies of prime material which might otherwise be difficult to obtain directly from the works. It is also intended that a wide range of sheet qualities, sizes and gauges should be kept available in stock at the warehouses of these firms to meet urgent and prompt delivery requirements from direct consumers. The appointed merchants are: John Cashmore, Ltd., Newport, Mon.; Ductile Steels, Ltd., Jubilee Works, Willenhall, Staffs.; John Lysaght (Bristol Works), Ltd., 66, Cannon Street, London, E.C.4; and Roberts, Sparrow and Co., Ltd., St. Mark's Street, Wolverhampton, Staffs.

Etablissements Johnson, Matthey et Cie., S.A.

A new Johnson Matthey associate company came into existence recently when the inaugural general meeting of Etablissements Johnson, Matthey et Cie., S.A., took place in Paris. The issued capital is Frs. 40,000,000 of which Johnson, Matthey and Co., Ltd., hold 81½%. The company has been formed to develop Johnson Matthey sales in France. It has taken over the merchanting business of M. Pierre Motton, who has worked in close collaboration with the London company since 1917, when his family became agents for the sale in France of Johnson Matthey products for the ceramic industry. The new company has also absorbed the business of Maurice Carrière et Cie., who acted as correspondents in France for the Bullion Department of Johnson Matthey. The offices are in the centre of Paris, between the Gare St. Lazare and Place de l'Opera, at 76 Boulevard Haussmann.

Fulmer Research Institute

The Fulmer Research Institute has recently installed an electron microscope (Metropolitan-Vickers Type EM.3.A) and is now able to undertake studies on particle shape and size. The instrument, which under favourable conditions will give a resolution of 20 Å, will be used for metallographic work and for oxidation studies, etc. It can readily be adapted for structure analysis by electron diffraction.

M-V Drive for Scunthorpe Plate Mill

The Appleby-Frodingham Steel Co. (a branch of the United Steel Companies, Ltd.), which is replacing one of its finishing plate mills, has ordered from Metropolitan-Vickers Electrical Co., Ltd., electrical equipment worth about £350,000. This will be used on a new four-high reversing hot mill to be installed at the Appleby Steelworks, Scunthorpe, Lincolnshire. The mill will take steel slabs weighing up to 16,000 lb. and roll them into plates up to 65 ft. in length and 11 ft. 4 in. finished width. The minimum plate thickness at this width is 0·3 in. The new hot mill will be driven by two 4,000-h.p. 40/100 r.p.m. D.C. motors, arranged as a twin-motor drive capable of a maximum total output of 24,000 h.p. The motors will be supplied from a 6,400-kW. flywheel motor-generator set having a peak capacity of 19,200 kW. In addition to being responsible for the supply,

erection and commissioning of the main electrical machines, control equipment and cables, Metropolitan-Vickers will also act as main contractors for the ventilating plant, which will supply 500,000 cu.ft./min. of filtered air to the machines and substation. The whole plant is due to go into production during 1958.

Blast Furnace Contract

PLANS for a large increase in productive capacity have already been announced by The Steel Company of Wales. These will involve additional coke ovens, a new blast furnace, and another ore unloading and stocking bridge, as well as novel and extensive additions to the steel-making and rolling-mill departments. It is now made known that Ashmore, Benson, Pease & Company of Stockton-on Tees, a member firm of the Power-Gas Group, has been entrusted with the construction of the blast furnace and the unloader and stocking bridges. The value of these contracts is approximately £2m.

The furnace will be the fifth that this Stockton firm has built for the Steel Company of Wales since the end of the second world war, and, like the predecessors, it will again demonstrate the further progress that has been made in this important branch of the industry. No. 5 is designed to be the largest known to the western world, and will be charged mainly with ores that have been prepared and enriched by sintering. The ore unloading and stocking bridge will also be the fifth of these units to be supplied by the same makers. This array of unloading equipment will discharge ore-carriers at a rate which far exceeds the facilities at any other port in the country.

Library Scholarships

THE Scholarship and Student Loan Fund Committee of the Special Libraries Association announces two $700 scholarships to be granted for the academic year 1957-1958 for graduate study in librarianship, leading to a degree at an accredited library school. Applicants must be graduates of high academic achievement, and application forms and details of eligibility for the award can be obtained from the Executive Secretary, Special Libraries Association, 31, East Tenth Street, New York, 3, N.Y.

High Vacuum Melting

MESSRS, DELAPENA & SON. LTD., Zona Works, Cheltenham have been appointed the sole agents in the United Kingdom for Balzers high vacuum melting and coating equipment, and will be glad to supply technical information concerning the use of this type of equipment to any interested companies. Messrs, Delapena & Son, Ltd., are also in a position to supply suitable high-frequency heating units of the motor generator type for the operation of the vacuum melting and coating units.

The Mond Magazine

For more than 25 years, The Mond Nickel Co., Ltd., have published the *Nickel Bulletin* which provides a monthly summary of the world's current literature on nickel and nickel-containing materials. A new publication *The Mond Magazine*, recently made its appearance, which is intended to have a wider scope and different functions: it will not in any way supersede the *Bulletin*. The Company's aim in the new publication is to provide interesting and readable illustrated articles and notes on subjects related to all its products, and to those of its associates, who extract from the mineral-rich areas of the Sudbury district of Ontario not only nickel but copper, cobalt, gold, silver, the platinum metals, selenium, tellurium, sulphur and iron ore. It is believed that a wide circle of readers will not only find special and direct interest in some of the material which the magazine contains, but will also derive pleasure, and perhaps profit, from the reading of articles which have a less direct bearing on their particular avocation.

Personal News

BRITISH INSULATED CALLENDER'S CABLES, LTD., announce the appointment of MR. K. COLLINSON, as Branch Manager, Leeds, in succession to MR. J. R. TOMMIS, whose death was recently announced.

MR. C. F. HUEBNER, who has been Chief Buyer for the British Oxygen Co., Ltd., since 1947, has been elected Chairman of the Purchasing Officers' Association.

THE appointment is announced by British Physical Laboratories, Ltd., Radlett, of MR. J. W. RIDLEY, in the capacity of Sales Manager for both this Company and the Quadrant Meter Co., Ltd. Mr. Ridley joined the Company at the beginning of this year, his previous position being with Magnetic and Electrical Alloys, Ltd.

MR. T. PARKER has been appointed a Director of Andrews Toledo, Ltd., and Andrews Toledo (Wire Rod), Ltd., companies belonging to the Darwins Group.

NORTHERN ALUMINIUM CO., LTD., announce several new appointments within their Sales Department: MR. D. W. TAYLOR, formerly Assistant Manager of the Company's Sales Development Division, has succeeded MR. G. A. VERNON, who has retired, as Manager of Birmingham Area Sales Office. Mr. D. A. PINN, previously Manager of Bristol Sales Office, has been appointed Export Sales Manager. He is succeeded by MR. H. M. LOUCH, previously Manager of Leeds Area Sales Office, which is now under the management of MR. H. Q. LIEVESLEY. MR. D. L. ROPER has been appointed Manager of Southampton Region Office, with effect from October 1st. in succession to MR. N. P. CAMPBELL, who is to attend a year's course at the Centre d'Etudes Industrielles, Geneva, sponsored by the Aluminium Limited Group of Companies.

HEAD WRIGHTSON & CO., LTD., announce that, with the consent of the Distillers Company, they have appointed MR. P. DAVIDSON as head of their nuclear power plant activities. Mr. Davidson, who has been Project and Construction Manager with the Engineering Division on the industrial side of the Distillers Company's activities, has wide experience in the construction of large complex chemical plants. He was with D.C.L. for 10 years, and previously with the Shell Refining and Marketing Company and Foster Wheeler, the well-known American boilermakers.

THE Parent Company of the 600 Group recently announced that it had changed its name to The George Cohen 600 Group, Ltd., and transferred its trading activities to a new wholly-owned subsidiary called George Cohen Sons & Co., Ltd. In addition to those who are already on the Board of the Holding Company, the following—all of whom have held high executive positions with the Company for many years—have been appointed Directors

of the new Subsidiary Company: Mr. J. A. J. Blanckensee, Mr. D. W. Cooper, Mr. A. S. Gill, Mr. C. E. G. Nye, Mr. J. H. Pawley and Miss E. P. Wood. Mr. J. A. Dewhurst and Mr. P. H. Ogden, have been appointed Local Directors of the Subsidiary Company and will continue to operate from their headquarters at the Company's Works at Leeds and Sheffield, respectively.

Major-General C.A.L. Dunphie, C.B., C.B.E., D.S.O., a Director of Vickers, Ltd., has been appointed Managing Director of the Company with effect from October 1st, 1956. Major-General Dunphie is Chairman and Managing Director of Vickers-Armstrongs, Ltd. He is also Chairman of Vickers-Armstrongs (Aircraft), Ltd., Vickers-Armstrongs (Engineers), Ltd., and Vickers-Armstrongs (Shipbuilders), Ltd., and a Director of a number of other Companies within the Vickers Group.

Davy and United Engineering Co., Ltd., announce that Mr. F. G. Phipps has been appointed a Director of their Middlesbrough subsidiary company, Davy and United Roll Foundry, Ltd., the well-known Tees-side manufacturers of rolls and steel castings.

Mr. A. Knowles, Manager of the Wembley works of British Oxygen Gases, Ltd., has been appointed Technical Manager, Acetylene, at the Company's headquarters at Bridgewater House. He takes over the position formerly held by Mr. E. A. Groom, who is taking up an appointment with the parent organisation, the British Oxygen Co., Ltd. The new District Manager at Wembley is Mr. D. R. Harris, formerly Assistant Production Manager at the Head Office, British Oxygen Gases, Ltd. Mr. R. J. C. Bryce has been appointed District Manager of the Scottish Division.

Mr. W. B. Lane, Managing Director, of Rapid Magnetic Machines, Ltd., Birmingham, is making a world trip in a drive for increased exports of the Company's specialised separation, extraction and lifting equipment. The journey will be by air, and the itinerary includes India, Ceylon, Singapore, Australia, New Zealand, U.S.A. and Canada.

Mr. Airey Neave, D.S.O., O.B.E., M.C., Member of Parliament for Abingdon, Berks., has joined John Thompson, Ltd., Wolverhampton, as their legal adviser. Mr. Neave's constituency includes the Harwell Atomic Research Establishment and he has a particular interest in atomic energy. He is a frequent speaker on the subject in the House of Commons.

Mr. W. A. Hartop, Works Director of George Kent, Ltd., left recently on a 20,000 tour of Canada and the U.S.A.—his fourth trip to Canada in two years. Mr. Hartop plans first to spend some time in Toronto, generally reviewing the present status and progress of the Kent maufacturing subsidiary there, Kent-Norlantic Ltd.

Mr. F. W. Martin has been appointed to the Board of Tube Investments, Ltd. The Deputy Chairman of a number of the Group's subsidiary companies in its Electrical and Steel Tube Divisions, Mr. Martin has served T.I. since its formation in 1919. He played a major part in the establishment in this country of the electric resistance welded tube industry.

Mr. D. H. G. Ince, D.F.C., has joined British Oxygen Arc Equipment, Ltd., as Sales Manager.

Obituary

We regret to record the deaths of the following :—

Mr. Basil Gray, who died on October 7th, only a week after retiring from executive duties and relinquishing his appointment on the Board of English Steel Corporation, Ltd. Mr. Gray, who was 68, was educated at Winchester and Cambridge, where he took a special degree in engineering and modern languages. He joined Vickers, Ltd., in 1910, and after holding positions in various departments he was, on the formation of English Steel Corporation, Ltd., in 1929, put in charge of the Central Estimating Department, and was later appointed Technical Assistant to Colonel Neilson and Mr. G. R. T. Taylor, In 1934 he was appointed Superintendent of Grimesthorpe Works, and was responsible during the war period for foundry production including large quantities of armour castings and heavy bombs. At the end of the war he was made responsible for engineering arrangements for all works, and was appointed a Director in 1946.

Mr. Gray was a member of many technical committees and in 1947 visited the U.S.A. to present to the American Foundrymen's Association an exchange paper on the manufacture of heavy bombs.

Professor Dr. Georg Masing, the distinguished German metallographer and teacher, who died at his home in Göttingen on Wednesday, 3rd October, 1956. Born in St. Petersburg in 1885, Dr. Masing studied under Professor G. Tammann at Göttingen and received his doctorate in 1909 for a thesis "On the formation of compounds under pressure and the reactions of metals in the solid state". Following a period in industry, during which he carried out extensive experiments in many fields, Dr. Masing accepted in 1937 the appointment of Director of the Institut für allgemeine Metallkunde at Göttingen University, a position which he held in succession to Professor Tammann, until his retirement a few years ago. Dr. Masing's work covered a great range of metallurgical subjects, both theoretical and practical, which included the development of the alloys of beryllium in co-operation with O. Dahl. He published his comprehensive "Lehrbuch der allgemeinen Metallkunde" in 1950.

The Deutsche Gesellshaft für Metallkunde awarded him the Heyn Medal in 1937, and in 1952 the Technical University of West Berlin made him an honorary Doktor-Ingenieur. In 1953, Dr. Masing received the Platinum Medal of the Institute of Metals in recognition of his outstanding contributions in the field of metallography.

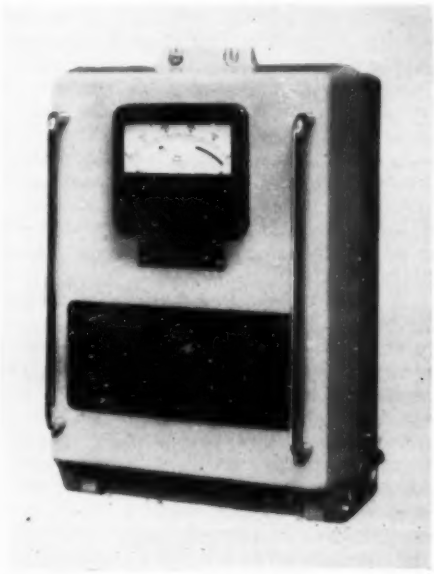
Dr. David Binnie, Chief Metallurgist of the Lancashire Steel Corporation, Ltd., and a Director of the Whitecross Co., Ltd., Warrington, who died on October 3rd, 1956, at the age of 58. Dr. Binnie was educated at the Royal Technical College, Glasgow, where he graduated in Ferrous Metallurgy in 1924. He obtained the degree of Doctor of Philosophy for published work on the overstraining of steel, and was later awarded an Andrew Carnegie Research Scholarship on behalf of the Heterogeneity of Steel Ingots Committee. Dr. Binnie joined the Lancashire Steel Corporation, Ltd., in 1931, and has since published several papers concerned with rimming and killed steel ingots.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Nucleonic Level Indicator

A NUCLEONIC level indicator recently introduced by the Baldwin Instrument Company, overcomes many of the shortcomings of existing equipment by making use of gamma radiation. A gamma-emitting isotope is placed on one side of a container and a detector on the other. Radiation passes from the isotope through the container to the detector, which is in fact a geiger counter. The output from the detector is proportional to the amount of radiation which it receives. In practice then, when the contents of a container are below the radioactive "beam," maximum radiation will be received by the detector. When the contents rise and cut the "beam," the radiation reaching the detector will be substantially smaller. The difference in radiation reaching the detector is shown as a difference in electrical output from the geiger counter, and this is arranged to operate a relay. The indicator unit shown in the illustration houses the relay and two lamps, which indicate whether the "beam" is broken or not. It is a relatively simple matter to incorporate the relay in some automatic control circuit. For complete control, two heads can be fitted to the container, thereby giving indication when the contents reach both maximum and minimum levels. Alternatively, a movable head can be fitted so that the "level" can be determined at any given time.



As the operation of the relay is dependent in the first instance on the *difference* in radiation, it is possible to detect the boundary between say two liquids having substantially different densities. This is simply because the lower the density, the greater will be the amount of radiation which will pass through.

The great advantage of this type of indicator is that nothing needs to be inserted in the container. Both the isotope and the detector are simply fixed to the outside. This fact is obviously of great consequence to installations involving control of corrosive liquids, materials at very high temperatures, liquid gases in pressurised vessels, etc.

Considerable care has gone into the design and manufacture of this instrument in order to ensure the highest possible degree of reliability. There is, in fact, very little that can go wrong. The isotope will emit gamma radiation, come what may. The electrical components have been chosen and the circuit specially designed to give maximum trouble-free service. The equipment in both the detector and the indicator unit are housed in robust dust-proof metal cases, and are fitted on anti-vibration mountings. It is obvious that there are very few requirements of level indication and control which cannot be met by this instrument; each installation, however, must be treated on its own merits.

Baldwin Instrument Co., Ltd., Brooklands Works, Dartford, Kent.

Solid Degassing Agent

A MAJOR problem in the production of sound castings in non-ferrous alloys is the absorption of gases, chiefly hydrogen, by molten metal. The subsequent gas release on cooling and solidification in the mould can result in a porous and even spongy casting. The introduction of a new solid degassing agent, which will overcome this problem, is announced by British Oxygen. Known as Calcyan, it can be used for the degassing of high melting point non-ferrous metals and alloys, and is based on calcium cyanamide. Calcyan can be held beneath the melt surface by means of a perforated plunger, and nitrogen is evolved by thermal decomposition. At the same time, the strongly reducing properties of the material will assist in deoxidation of the melt.

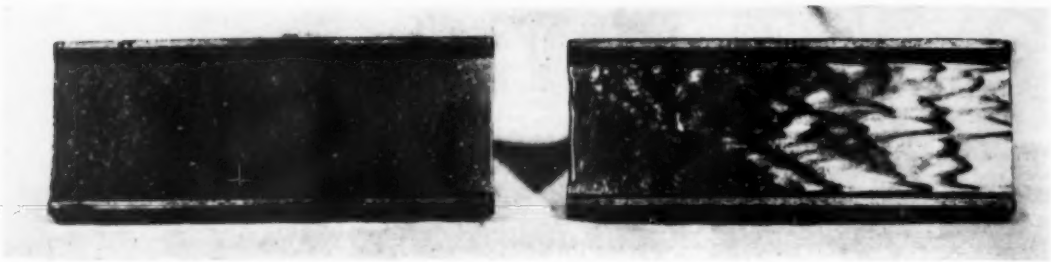
The general method by which a melt is degassed is by the release under its surface of another gas which will not dissolve or react with the metal. This insoluble gas sweeps out the undesirable gas in solution. Where copper-base alloys are used, gaseous nitrogen is frequently employed, and is let into the melt by means of an immersed probe. This method has certain disadvantages where small foundries are concerned, because of the size of the equipment and the degree of control required to obtain satisfactory results.

The amount of Calcyan required varies according to the melting practice used. Degassing in large deep bath melting units will generally require less Calcyan than where degassing is carried out in smaller melting crucibles.

The British Oxygen Co., Ltd., Bridgewater House, Cleveland Row, London, S.W.1.

Wheelabrator Steel Shot

THE value of cast steel shot as an abrasive cleaning medium has for some time been appreciated in the U.S.A., and a major advancement in shot blasting practice in this country is portended by the news that Tilghman's, Ltd., in conjunction with their associate



Wheelabrator blades after 103 hours running: left—using cast steel shot; right—using crushed shot.

company, Bradley's (Darlaston), Ltd., are now producing cast steel shot on a commercial basis.

Wheelabrator steel shot is produced from electric furnace steel which is given a double heat treatment to produce a tempered martensite micro-structure, resulting in a shot with an unique degree of toughness, solidity, uniformity and operational efficiency. The micro-structure of shot is the primary factor in determining such major issues as cleaning speed, shot life, and plant maintenance under subsequent operational conditions.

Tests carried out on various types of Wheelabrator plant on a wide range of workpieces have shown the superiority of this steel shot over chilled iron shot. Steel shot had an effective life approximately 6–8 times that of chilled iron shot, the average saving in cost per ton cleaned being 26·3%. The life of protective wearing plates coming within the effective area of the shot blast stream was increased by 56%, and of other machine parts, within an area subject to shot ricochet, by as much as 200–300%. Blade wear was also reduced, as can be seen from the illustration, which shows blades after 103 hours running.

The finish obtained by Wheelabrator steel shot is more matt in appearance than is obtained when using chilled iron shot, mainly due to the frictional action set up by the steel shot at the point of contact. Iron shot, under similar circumstances, breaks down and shatters. The cleaning time is reduced by between 5 and 10%.

Whilst the original cost of Wheelabrator cast steel shot is higher than conventional chilled and heat treated iron abrasives, against this must be set the saving in amount of shot used, reduction in blast cleaning time, lower expenditure on replacement of wearing parts, longer periods of productivity without stoppage for servicing, and less maintenance engineers' time, etc. When all these factors are taken into consideration, a reduction of 15 to 25% in overall operating costs can be effected.

Tilghmans, Ltd., Broadheath, Altrincham.

New Gun for Philips Stud Welding Process

A NEW and improved type of gun for their stud welding process, introduced by Philips Electrical, Ltd., incorporates several new features. The barrel is now hollow so that the reverse end of studs can be accommodated inside the gun. This arrangement permits use of $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$ or $\frac{1}{2}$ in. mild steel studs up to a maximum length of 8 in. with the standard support leg. Special studs are not required—any normal plain or threaded type is satisfactory—and standard mild steel wire nails, split pins, wood screws, countersunk and cheese-headed B.A. screws can also be welded. A high degree of accuracy in placing studs is possible, since the support leg is fitted with a position foot, the edges of which are bevelled so that the hairline register marks can be perfectly aligned with centre-lines scribed on the workpiece.

When the gun is loaded, the amount by which the stud projects beyond the plane of the support leg tips affects the quality of welds. To permit ultra-fine control of this distance, therefore, the gun is now fitted with a vernier adjustment. Another refinement which has been added is that of three different spring tensions to alter the pressure with which the stud is forced into the weld pool. These can be varied to suit overhead, vertical or downward operation. Like its predecessor this new Philips gun has the great advantage of being suitable for operation from any standard A.C. arc welding transformer giving a minimum of 70V. open circuit: special plant is not necessary.

Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

Liquid Level Switch

A NEW liquid level switch of advanced design has been developed by Teddington Industrial Equipment, Ltd., for the control and indication of liquid level in tanks, boilers, sterilisers and all types of industrial vessels. Operating on an entirely new principle, this switch, designated type WX, has no moving parts, yet is capable of switching loads up to 5 amp. at 250 volts A.C. without subsidiary amplifiers or relays, and is particularly suitable for installation where the interior of the vessel being controlled is not readily accessible for cleaning or repairs, since it requires no maintenance whatsoever.

The WX liquid level switch is a thermal instrument operating on a difference in heat transfer between the sensitive element and the liquid in the vessel, or the sensitive element and the vapour; not on the difference in temperature or latent heat. This principle (protected by U.K. Patent No. 565,309) gives a very sensitive response, changes of level in the order of $\frac{1}{4}$ in. being sufficient to operate the switch. The operating mechanism is temperature-compensated, and the instrument is therefore unaffected by temperatures from 0 to 350° F.

It also provides an automatic surge damping effect, since a positive change in level of sufficient duration to affect the heat transfer rate is necessary before the switch will operate. This entirely eliminates short-cyling caused by momentary changes in level, which is an important advantage in installations normally subject to surging or vibration.

Two models are available, offering alternative methods of mounting, and production will commence next month.

Teddington Industrial Equipment, Ltd., Sunbury-on-Thames, Middlesex.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
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The Determination of Phosphorus in Low Carbon Ferro-Chrome

By B. Bagshawe and A. L. Pill

The Brown-Firth Research Laboratories, Sheffield.

In this article the authors indicate the inhibitive effect of high chromium concentrations on the precipitation characteristics of ammonium phospho-molybdate, and recommend for the determination of phosphorus in low carbon ferro-chrome a method based on the British Standard method for steels after a preliminary volatilisation of chromium as chromyl chloride.

THE phosphorus content of low carbon ferro-chrome is important because, in the manufacture of high chrome stainless and heat-resisting steels, the alloy may constitute up to as much as one third of the charging materials. A 70% Cr ferro-alloy, high in phosphorus, e.g., 0·06%, if used to supply the total chromium requirements of 20/25% Cr rustless steel, would itself add 0·02% phosphorus to the finished steel. Even when smaller amounts are used, as for example, when stainless scrap forms a proportion of the charge, or when lower chromium grades are being made, the phosphorus increment from the ferro-alloy is still a significant factor in relation to the phosphorus content of the finished steel.

Experience with the traditional methods of determining phosphorus has indicated that unreliable and inconsistent results may be obtained when such methods are applied to ferro-chrome.

In the present investigation, some indication is given of the inhibitive effect of high chromium concentrations on the precipitation characteristics of ammonium phospho-molybdate, and recommendations are made in which the British Standard method for steels can be used after a preliminary volatilisation of chromium as chromyl chloride.

Investigation

(*a*) *Traditional Fusion Method*

The traditional method of determining phosphorus in ferro-chrome (high carbon alloy) is based on decomposition of the powdered alloy by dry fusion with sodium peroxide. This is followed by acid extraction and precipitation as ammonium phospho-molybdate, with or without an intermediate separation of the phosphorus together with iron, from the chromate, by means of ammonia.

Experience with this method has indicated that it hardly meets third figure accuracy requirements, and in some circumstances it may give results which are not only erratic, but grossly high. This may arise if the acidity of the fusion extract is not correctly adjusted to give optimum conditions for the precipitation of phospho-molybdate conforming strictly to theoretical formula and uncontaminated with free molybdic acid. Erratic blanks deriving from the nickel crucibles in which the fusions are made are another factor to be considered. Nickel crucible material may contain up to 0·01% P and tests have shown that very variable amounts, ranging from 0·3 g. up to as much as 2 g., may be removed in a single fusion, depending on the time required and the intensity of the fluxing reaction, both of which are governed by the individual characteristics of particular alloys. Moreover, it is not possible to make adequate compensation for these effects by means of blank corrections, as blank fusions develop no exothermic heat and, consequently, remove practically none of the crucible material.

It is also difficult to apply the fusion method to more than 1 g. test samples.

(*b*) *Acid Solution Procedure*

As low carbon ferro-chrome is soluble in mineral acids, it seems more reasonable to base its determination on acid solution methods, i.e., on lines closely following the standard method for steels.

It is essential that the initial decomposition of the alloy be carried out in strongly oxidising mixtures, otherwise there may be loss of volatile phosphorus compounds and consequent low results. This requirement is not so easily met with ferro-chrome as it is with steel, as ferro-chrome shows varying degrees of passivity in strongly oxidising acid mixtures. For example, the acid mixture (15 ml. HNO_3, 25 ml. HCl) used in the standard method for steel (B.S.1121 : part 9 : 1948) cannot be used for ferro-chrome. Tests with various nitric-hydrochloric acid mixtures indicated that an appreciably weaker mixture, e.g., 15 ml. HNO_3, 70 ml. HCl, would be required. In mixtures containing higher proportions of nitric acid than this, there was always some passivity, and with some of the more strongly oxidising mixtures there were sometimes spasmodic alternations of rapid attack followed by passivity and then renewed attack. Addition of bromine to nitric-hydrochloric acid mixtures always resulted in passivity, but rapid and complete attack was obtained with bromine-hydrochloric acid mixtures without nitric acid.

Tests with the 15 ml. HNO_3, 70 ml. HCl mixture

TABLE I.—RESULTS ON SYNTHETIC IRON-CHROMIUM SERIES.

Iron (g.)	Chromium (g.)	Equiv. Chromium (%)	Phosphorus Found (%)	
			0·025% present	0·050% present
1·7	0·3	15	0·024	0·050
1·6	0·4	20	0·024	0·049
1·5	0·5	25	0·024	0·047
1·4	0·6	30	0·022	0·048
1·3	0·7	35	0·023	0·046
1·2	0·8	40	0·021	0·046
0·6	1·4	70	0·019	0·040
nil	2·0	100	0·006	0·018

proved that the conditions were still sufficiently oxidising to retain all the phosphorus. This was confirmed by dissolving the test sample with this mixture in a closed flask fitted with a bromine trap head. No phosphorus was recovered from the trap. Similarly, solution in bromine-hydrochloric acid mixture (5 ml. Br_2, 25 ml. HCl) was also proved to be satisfactory. We prefer the nitric-hydrochloric acid mixture, however, because if decomposition is inclined to be prolonged, the bromine-hydrochloric acid mixture may become impoverished in bromine before solution of the metal is complete, and hence there may be some risk of losing phosphorus. In the subsequent work, therefore, we have used nitric-hydrochloric acid mixtures in ratios ranging from 15 HNO_3 : 50 HCl, in which most low carbon ferro-chromes are soluble, up to 15 HNO_3 : 70 HCl which has covered all samples that have been examined.

(*c*) *Effect of High Chromium Concentration on the Phospho-Molybdate Precipitation*

Using the modified acid solution procedure, the conditions are apparently suitable for the direct application of the standard method for steels (B.S.1121 : part 9 : 1948). This is based on perchloric acid, with arsenic removal as volatile tribromide, precipitation of the phosphorus as ammonium phospho-molybdate, and gravimetric determination of the molybdenum equivalent, after conversion to lead molybdate.

Preliminary experience in applying this B.S. procedure to ferro-chrome showed that, for a given amount of phosphorus, precipitate formation was appreciably slower than it is for steels, and if the usual standing time was allowed before filtration, the results were generally appreciably low. For example, in some instances, as little as 0·03% P was found in synthetic samples known to contain 0·05% P. The phospho-molybdate precipitates from commercial alloys were also often strongly discoloured, varying from orange to dark brown. This was at first attributed to vanadium impurity, but it was later found to be an effect produced by chromium. These discoloured precipitates always contained chromium, possibly in some form of combination, as distinct from mere mechanical or adsorptive co-precipitation.

By prolonged shaking to encourage precipitate formation, and by standing for longer periods before filtration, e.g., 16–24 hours, it was found possible to recover all, or nearly all, the phosphorus and obtain results within acceptable accuracy limits for most practical purposes. For example, values of 0·044–0·046% P could be obtained consistently, on a sample later shown to contain 0·048% P. Such a procedure, however, is much too slow for routine purposes, and we were forced to consider other possibilities.

The retarding action of chromium on the phospho-molybdate precipitation is shown by the typical results obtained on a synthetic iron-chromium series at two phosphorus levels, i.e., 0·025 and 0·050% P (see Table I). The general conditions of determination were according to B.S.1121 : part 9 : 1948.

It will be seen that although the pattern is not strictly regular, there is a definite trend showing that recovery becomes progressively more incomplete with increasing chromium content. There is no marked suppressive effect up to about 30% Cr, and it is this circumstance which has permitted the method to be used for steels, without incurring significant error. Above this level of chromium, however, suppression begins to assume practical importance, and in the chromium range 60–100%, which includes the steel-making ferro-alloys and chromium metal, there is definite negative error.

We also found that the magnitude of error is influenced by the state of the chromium. For example, hexavalent (chromate) chromium is a more potent suppressive agent than is trivalent chromium. This may be of some practical significance because it is not easy to be sure that no re-oxidation to the hexavalent condition occurs in the hot perchloric acid concentrate after the arsenic removal treatment. There may also be increased contamination of the phospho-molybdate precipitate by adsorptive occlusion of chromate, and when this occurs, the subsequent lead molybdate precipitates are contaminated with lead chromate. In extreme cases (e.g., 2 g. of chromium metal, dissolved and fully oxidised with perchloric acid before carrying out the molybdate precipitation) there may be complete, or almost complete, suppression of phospho-molybdate precipitation.

(*d*) *Removal of Chromium*

To circumvent the inhibitive action of high chromium concentration, we introduced a chromyl chloride volatilisation treatment at the perchloric acid fuming stage. Since it is not necessary to remove all the chromium, but merely to reduce its concentration below interference level, a quick and simple form of volatilisation treatment is all that is necessary. We found, in fact, that three or four 10 ml. additions of hydrochloric acid to the fuming concentrate, refuming after each addition, reduced the chromium concentration to the equivalent of less than 1%. For example, determination of residual chromium in the solution extracts from a test series of 70% Cr ferro-alloy, after the above treatment, gave the following values :—

0·64, 0·56, 0·73, 0·45, 0·52, 0·57, 0·43, 0·83% Cr

If this step is introduced to reduce the chromium concentration, phosphorus can then be determined by the B.S. method, with the same accuracy as for steel.

The following recommended procedure is based on the B.S. method, with certain modifications of detail, and incorporating the chromyl chloride volatilisation treatment.

Method of Determination

(*i*) *Reagent Solutions*

All reagents should be of the highest purity and, in particular, perchloric acid and hydrobromic acid should be of Analar quality and known to give low phosphorus blanks.

Hydrochloric acid (2 : 98)—Dilute 20 ml. of hydrochloric acid (sp. gr. 1·16) to 1 litre.

Nitro-Molybdate Reagent—Make a suspension of 100 g. of molybdenum trioxide (98 to 100%) in 240 ml. of water. Complete solution of the acid by the addition of 170 ml. of ammonium hydroxide (sp. gr. 0·880).

Pour the solution, with repeated shaking, into 1,250 ml. of nitric acid (sp. gr. 1·20) containing 0·04 g. of microcosmic salt. Stand overnight and filter.

Nitric Acid (2 : 98)—Dilute 20 ml. of nitric acid (sp. gr. 1·42) to 1 litre.

Ammonium Hydroxide (1 : 1)—Dilute 500 ml. of ammonium hydroxide (sp. gr. 0·880) to 1 litre.

Bromo-Cresol Purple (0·2%)—Dissolve 0·2 g. of reagent in water and dilute to 100 ml.

Ammonium Chloride (25%)—Dissolve 250 g. of ammonium chloride crystals in water and dilute to 1 litre.

Lead Acetate (1%)—Dissolve 10 g. of lead acetate crystals in water and dilute to 1 litre.

(*ii*) *Procedure*

Transfer 2 g. of sample (Note 1) to a 400 ml. R.P. flask, add 15 ml. of nitric acid (sp. gr. 1·42) and then 50 ml. of hydrochloric acid (sp. gr. 1·16) (Note 2). When dissolved, add 35 ml. of perchloric acid (sp. gr. 1·54) and evaporate to fumes.

When the chromium appears to be fully oxidised, remove the flask from the hot plate and immediately add 10 ml. hydrochloric acid (sp. gr. 1·16). Return the flask to the hot plate and heat strongly until the residual chromium is again fully oxidised, and repeat the hydrochloric acid treatment. Repeat these alternate operations of heating the solution to oxidation of the chromium and treating with hydrochloric acid twice more, making four treatments in all.

Cool slightly, add 10 ml. of hydrochloric acid (sp. gr. 1·16) to reduce residual chromium, dilute with 25 ml. of hot water, boil for 3 minutes, filter through a paper pulp pad into a 500 ml. R.P. flask, and wash several times with small quantities of hot dilute hydrochloric acid (2 : 98). The pad containing the siliceous residue can be discarded.

To the filtrate add 10 ml. of hydrobromic acid (sp. gr. 1·46), and evaporate to fumes, with the beaker uncovered, but avoiding re-oxidation of the residual chromium. Cool slightly, redissolve in 25 ml. of hot water and dilute to 75 ml.

Add 8 g. of ammonium nitrate, adjust the temperature to 80° C., add 35 ml. of cold nitro-molybdate reagent (freshly filtered) and shake vigorously until the precipitate forms. Allow to stand at room temperature overnight (Note 3).

Filter through a pulp pad and wash with cold dilute nitric acid (2 : 98) (Note 4). Transfer the funnel and filter to the neck of the original 500 ml. R.P. flask, and dissolve the precipitate through the pad with 15 ml. of dilute ammonium hydroxide (1 : 1) (Note 5). Wash twice with hot water, then re-filter the ammoniacal extract through the same filter pad into a clean 400 ml. beaker, and wash the filter repeatedly with hot water.

Neutralise with formic acid (sp. gr. 1·20) to the change point of bromo-cresol purple and add 2 ml. excess. Add 50 ml. of ammonium chloride solution (25%) and dilute to 200 ml. Heat to boiling and add *slowly* 40 ml. of lead acetate solution (1%), stirring continuously throughout the addition. Add a little macerated pulp and boil gently for 2–3 minutes. Filter through a pulp pad and wash with hot water. Ignite in a shallow capsule at a temperature not exceeding 650° C. Cool and weigh as lead molybdate ($PbMoO_4$).

TABLE II.—RESULTS ON SYNTHETIC SERIES WITH VARYING PHOSPHORUS CONTENT.

Phosphorus Added (%)	Phosphorus Found (%)	
	2 hours standing	16 hours standing
0·010	0·008	0·010
0·015	—	0·016
0·020	0·020	—
0·025	—	0·024
0·035	0·035	0·036
0·050	0·049	0·050
0·055	—	0·055

$$\frac{\text{Wt. of } PbMoO_4}{2} \times 0{\cdot}7 = \%\ \text{P.}$$

A blank test on all reagents should be operated concurrently, and its weight deducted from the test weight before making the calculation.

(*iii*) *Notes*

(1) For phosphorus contents exceeding 0·1% the weight should be reduced to 1 g.

(2) This operation should be carried out in a warm place, e.g., in front of a hot plate. The amount of hydrochloric acid specified is usually sufficient to effect solution of the sample, except perhaps in the case of very coarse drillings. If only a few particles of unattacked metal remain after reaction ceases, the test can be considered satisfactory. Otherwise it is necessary to take a fresh test sample and use an increased amount of hydrochloric acid, e.g., up to 70 ml. Alternatively the sample may be dissolved with 5 ml. of bromine and 25 ml. of hydrochloric acid, and the solution treated with 10 ml. of nitric acid before the perchloric acid addition.

(3) There may be appreciable crystallisation of ammonium salts on standing overnight, particularly in cold weather. This has no adverse effect, and is readily removed during filtration and washing. For routine purposes the standing period may be reduced to a minimum of 30 minutes.

(4) For routine purposes the determination may be completed volumetrically as follows :—

Continue to wash the precipitate with 2% potassium nitrate until the washings are acid free to methyl orange. Transfer the pad and precipitate to the flask, and then add a measured excess of N/6·74 sodium hydroxide from a burette. Add 50 ml. of cold, recently boiled, distilled water, and shake to break up pulp and dissolve the yellow precipitate. Titrate with N/6·74 sulphuric acid, using 10 drops of phenolphthalein solution (0·1%) as indicator, until 1 drop of acid just discharges the pink colour. The titrant solutions may be standardised against potassium phthalate or, alternatively, against a standard alloy of known phosphorus content.

(5) If the phosphorus content approaches 0·1% on the 2 g. weight basis, more ammonium hydroxide may be necessary to effect solution of the phospho-molybdate precipitate.

TABLE III.—RESULTS ON WORKS PRODUCTION ALLOYS.

Alloy No.	Recommended Method	Works Routine Method
1	0·023	0·025
2	0·024	0·025
3	0·024	0·025
4	0·023	0·024
5	0·024	0·026
6	0·025	0·026
7	0·025	0·026
8	0·026	0·027
9	0·024	0·026
10	0·023	0·024
11	0·025	0·026
12	0·024	0·025
13	0·025	0·027
14	0·024	0·026
15	0·026	0·026

Results

Using the foregoing method, the results set out in Table II were obtained on 2 g. samples of a synthetic series (30% Fe, 70% Cr) with additions of standard phosphorus solution covering the range 0–0·055% P. In some cases the ammonium phospho-molybdate precipitates were filtered after 2 hours, and in other cases after standing overnight (16 hours).

Results obtained on a series of fifteen works production alloys (70% Cr) are given in Table III, and for comparison the works control laboratory values are also given. These were obtained by the method in its quickest form, i.e., with minimum standing period (30 minutes) for the phospho-molybdate precipitation, alkalimetric titration finish, etc., in accordance with the notes addenda to the recommended procedure.

Conclusion

The results and data presented confirm the adequacy and reliability of the recommended method for phosphorus in low carbon ferro-chrome, for both standard purposes and for works routine requirements.

Acknowledgments

We thank Dr. C. Sykes, F.R.S., for permission to publish this paper. Acknowledgment is also made to John Brown & Company (Overseas) Ltd., for their assistant interest and encouragement throughout the work, and to Mr. J. Drynan, Chief Chemist, Rhodesian Alloys, Ltd., for advice on routine application and for contributing the works routine results.

Zinc Development Association Report

THE ZINC DEVELOPMENT ASSOCIATION has recently issued a report on its work, and on that of the Zinc Alloy Die Casters, Zinc Pigment Development and Hot Dip Galvanizers Associations. Together they form a group from which users all over the world can freely obtain authoritative information on zinc. The Z.D.A. is supported by all the producers of zinc metal and most zinc mining companies in the Commonwealth, and the affiliated associations by the leading United Kingdom firms in their industries, and by others in the Commonwealth and Europe.

This is the first report to be issued since the Z.D.A. moved to its new premises in Berkeley Square. Although the return to London was a major operation involving many staff changes, it provided an opportunity to review and re-plan much of the Association's work, and has undoubtedly improved the Z.D.A.'s national and international standing. The report contains an illustrated description of the new offices and reviews the improved information services now available to members and enquirers.

Membership of the group has expanded in recent years, and now includes many zinc users in the Commonwealth and Europe. International galvanizing and die casting conferences have been organised by the group, which has played a leading part in the formation of the European Pressure Die Casting Committee and the European General Galvanizers Association, for which it acts as Secretary. It is interesting to note that this work has led to the formation of national associations, modelled on the H.D.G.A. and Z.A.D.C.A., in many European countries.

The technical work of the Z.D.A. group has two main objects—to increase the range of applications of zinc and zinc products, and to improve the zinc using processes. The H.D.G.A. has issued recommendations on the design of parts for galvanizing and has recently published a paper on galvanizing pot construction. The Z.A.D.C.A. is at present drawing up standards similar to those issued in the U.S.A., for the guidance of engineers and designers, and is encouraging the manufacture of standard die parts. The Z.P.D.A. has been making practical application tests on paints based on zinc pigments, and has prepared definitions for the guidance of Government departments. The Z.D.A. is investigating new methods of roofing and joining zinc gutters and weatherings.

Although the Z.D.A. has no laboratories, it plays a prominent part in directing and encouraging research work of other bodies which it helps to finance. Among the subjects under investigation are the hot dip galvanizing process, the properties of galvanized coatings, and the properties of welds in galvanized steel. In zinc alloy die casting, most of the work has been focussed on finishes, and a special application of zinc at present under investigation concerns its use in protecting buried steelwork and underwater parts of ships.

The report concludes with a brief review of the growth of world zinc consumption in recent years and gives up-to-date statistics for the main countries. Copies of the report are available from the Association's offices at 34, Berkeley Square, London, W.1.

Bridge Across Space

THE pattern of our 20th century civilisation has been very largely determined by the spectacular advances in the science of communication made over the last 100 years. From the beginning, when Alexander Graham Bell had the notion of making a steel spring respond to the vibrations of the human voice, and thus generate an electric current of varying significant intensity, steel has played an important part in the production of devices for the transmission and reception of telecommunications. In a new film, "Bridge Across Space" is pictured the evolution of tele- and radio-communications from the early experiments of Faraday, Bell and Watson to the giant Rugby transmitters directing messages in never-ending streams to the Far East and the Americas, over the Arctic Circle and below the Antipodes; from the roof-top transmissions of Guglielmo Marconi to the world's greatest steerable radio telescope, now under construction at Jodrell Bank in Cheshire, which employs 2,000 tons of structural steel and is calculated to trace radio waves scattered round the globe by meteors sixty miles above the earth's surface; to transmit echoes to the moon and the planets; and to study the eruption of sunspots 93 million miles away.

This sound film is available in 16 mm. and 35 mm. sizes and is obtainable on free loan by writing to the Public Relations Department, British Iron and Steel Federation, Steel House, Tothill Street, London, S.W.1.

The Flame Photometric Determination of Lithium Using Infra-Red Barrier Layer Cells*

By H. J. Allsopp and P. M. Wingfield
Royal Aircraft Establishment, Farnborough.

Lithium is determined using potassium as an internal standard with a town-gas and air flame. The paper describes a double-beam instrument modified to incorporate infra-red barrier-layer cells which have peak response in the region of the lithium and potassium major lines. Long-term stability tests on the photo-cells were carried out and the effects of alloying constituents and acidity in the final solution have been studied. A method for determining lithium in magnesium-lithium-zinc alloys is given.

MAGNESIUM - LITHIUM alloys with a lithium content above 10% by weight crystallise in a cubic structure, which facilitates fabrication by forging, extrusion or rolling processes. The mechanical strength of such binary alloys, however, is not high, since these alloys are not responsive to heat treatment. Additions of silver, aluminium or zinc to magnesium-lithium alloys make possible precipitation hardening, which enhances the mechanical properties.

The determination of the constitutional diagrams of magnesium-lithium-zinc alloys was being made in the Establishment in order to study the properties of such alloys, and since a large number of lithium determinations was required, an existing internal standard flame photometer, similar to that described by Robinson and Ovenston,[1] was adapted for the purpose.

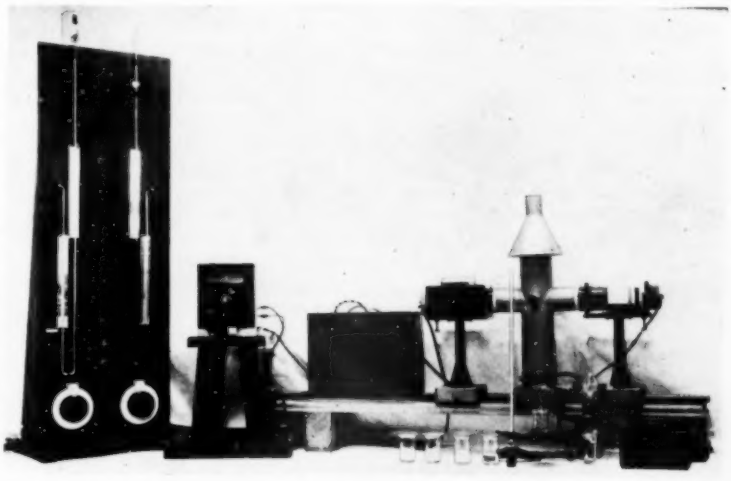

Fig. 1.—General view of the apparatus.

Apparatus

Fig. 1 shows the general layout of the flame photometer. Town-gas pressure is read on a water manometer, and compressed air is fed from a pressure-reducing valve to the atomiser through a reservoir containing water. The air pressure is shown on a mercury manometer. The final pressure controls are glass taps connected to vernier-type slow motion dials.

A diagrammatic sketch of the optical and electrical systems is shown in Fig. 2. From this it can be seen that the light from the flame passes through a two stage collimating system incorporating an iris diaphragm, which is used to attenuate either beam at will. The diaphragm is situated between the lenses in the collimated beam, so that variations of aperture do not alter the area of photocell illuminated, and enable the diaphragm to be used over its full range. The light then

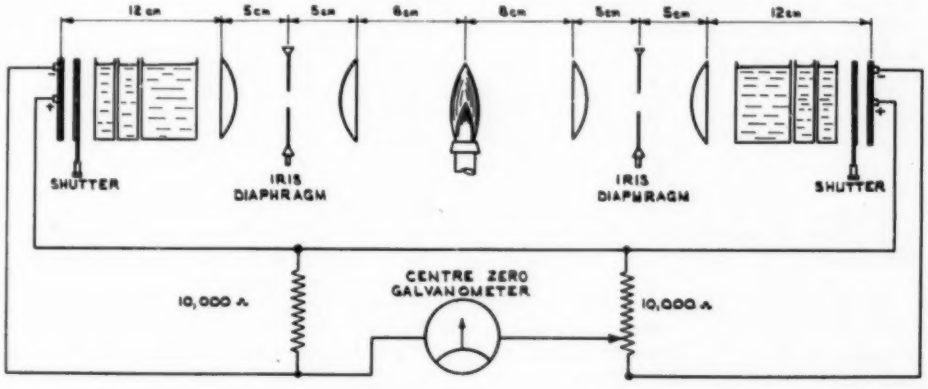

Fig. 2.—Diagram of electrical and optical systems.

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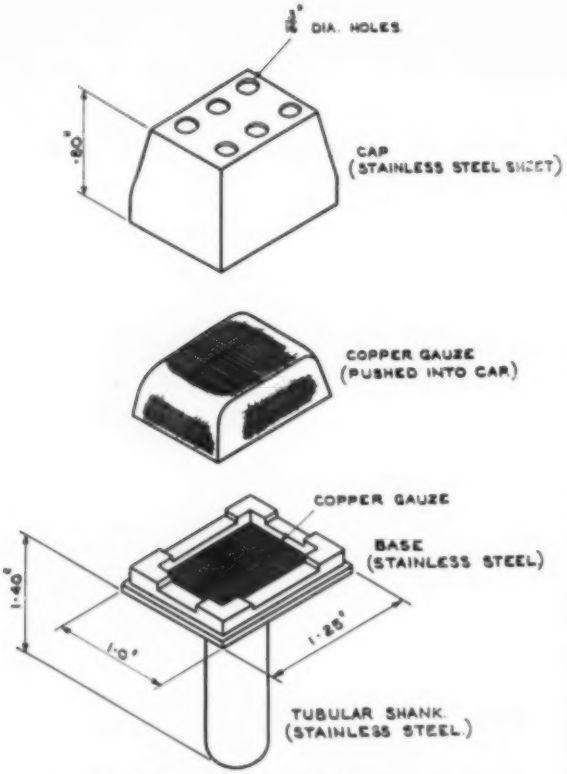


Fig. 3.—Exploded view of burner head.

passes through a heat absorbing water cell of 4 cm. optical depth, thence through the isolating filter and a shutter to the photo-cells. The filter assembly can be seen in Fig. 1.

The electrical circuit consists of a 10,000 ohm load resistance across each cell, and in the case of the potassium cell this takes the form of a high grade precision wire-wound potentiometer which is linear to ± 0·1%, whereas the lithium cell uses a fixed wire-wound resistance. The positive end of each resistance is common, and the galvanometer is connected between the negative end of the lithium cell and the slider of the potentiometer. Since the voltages across the resistances are proportional to the incident light, and in opposition, and since the potassium addition to the flame is sufficient to produce a higher voltage from the cell, a portion of this can be utilised to balance that produced by the whole of the incident lithium light.

The filters used consist in each case of two 1 cm. solution layers, the transmission bands of which combine to produce a spectral response curve which peaks sharply at the desired wavelength. In the case of lithium, the two solutions consist of rhodamine B and cupric chloride, and for potassium, aniline blue and potassium dichromate. These solutions are fully described by Robinson and Ovenston.[1]

No modification was necessary to the original atomiser, which is similar to that used by Domingo and Klyne,[2] but the burner, using town-gas and air, is of the Meker type constructed in stainless steel.

Modification of Existing Instrument

The original instrument, as described by Robinson and Ovenston,[1] was constructed primarily for the determination of sodium and potassium, using lithium as an internal standard. It was believed that the procedure could be reversed using potassium as an internal, standard for lithium with the same filters. Preliminary work showed that, while this was so, sensitivity was extremely low. Because high lithium contents were to be encountered, a high degree of accuracy was required if large errors were to be avoided at the higher levels.

The original burner was designed for use with cylinder gas, and, as town-gas was to be used, it was thought that if a greater area of flame were obtained, more sensitivity would result. A stainless-steel Meker-type burner head was constructed, and although the sensitivity was increased, it was still much less than that desired. Fig. 3 gives details of the burner.

Attention was next turned to the selenium barrier-layer photo-cells, which were severely lacking in response in the region of the potassium and lithium lines. An infra-red type was obtained having a much greater response in the near infra-red region. The spectral-response of the two types are compared in Fig. 4. Further work showed that these cells suffered from two major disadvantages. In the first place, the normal laboratory atmosphere had a deleterious effect on their life, and frequently affected them within 24 hours—sometimes even before use. This difficulty was overcome by mounting the cells in airtight containers. Details for the construction of these are given in Fig. 5. Secondly, the much lower internal resistance of these cells had a severe damping effect on the original galvanometer. Various other models were tried in an endeavour to overcome this, and eventually a satisfactory instrument was found having an internal resistance of 50 ohms., 1·5 metre beam, and a critical damping value of 1,200 ohms.

It had been postulated[1] that, by using photo-cells more sensitive to infra-red light, a more effective potassium filter would have to be used to avoid the passage of the 8130 Å lithium line. A spectrophotometer was used to determine the approximate emission of the 8130 Å line from the flame, and the amount was found to be negligible. We have found that the sensitivity of the cells is so great and the excess of potassium so large, that the small amount of lithium radiation, amounting to some 4% at 6700 Å, which passes through the potassium filter, has the effect merely of giving a slight curve to the standardisation graph, and is thus taken into consideration.

During the course of the investigation it was noticed that salts crystallised at the jet orifice, at the point where the solution met the air stream in the atomiser. This caused fluctuations in, and ultimate stoppage of the flow of liquid. This was due to the low humidity of the laboratory air supply. An air reservoir was constructed containing water, onto the surface of which the incoming air was directed. Loss of flame intensity occurred if the air was passed through the water, due to dilution of the solution. This unit was fitted to the low pressure side of the air supply immediately prior to the manometer, and no further trouble was experienced.

The instrument so far gave satisfactory results, but peculiar variations occurred which were finally traced to the atomiser. This had been assembled using ordinary stopcock grease, and during runs slight movement took place between the individual parts when solutions were changed. This trouble was overcome by assembling the

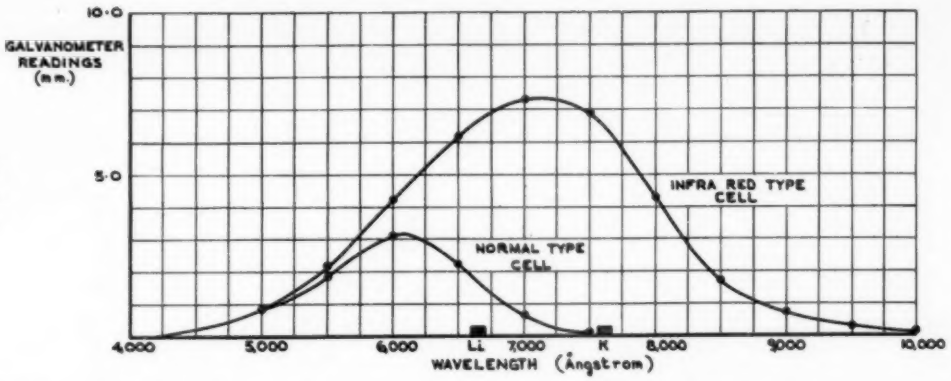


Fig. 4.—Comparison in response between normal and infra-red type photo-cells.

atomiser using hard black vacuum wax, the parts being adjusted to the point of maximum sensitivity whilst the wax was still fluid.

Long Term Stability Check on Photo-cells

It was considered advisable to carry out a series of readings on solutions of known composition, to give some measure of the stability of the infra-red cells after being mounted in their airtight containers. A number of solutions was prepared and the lithium contents determined. This was repeated at monthly intervals over a period of six months, a fresh calibration curve being made each time. These calibration curves showed negligible variations over the six-months period during which the series was run. The figures in Table I show the lithium percentage in magnesium-lithium-zinc samples, determined at monthly intervals from the same major solutions.

Application to Magnesium-Lithium-Zinc Alloys

Figs. 6, 7, and 8, show, respectively, that variations in acidity up to four normal, and in the concentration of magnesium and zinc up to 4 g./litre, can be tolerated in the final solution, but a tailing off of sensitivity occurs beyond this, probably due to increased viscosity in the case of the acid.

TABLE I.—LONG TERM STABILITY CHECK ON PHOTO-CELLS.

Sample No.	Lithium Content (%)						
	1	2	3	4	5	6	7
C20	1·13	1·08	1·12	1·08	1·19	1·17	1·12
L41	1·40	1·36	1·39	1·37	1·37	1·39	1·36
L44	1·18	1·16	1·15	1·15	1·16	1·17	1·15
L45	0·93	0·92	0·91	0·88	0·92	0·93	0·89
L46	0·90	0·90	0·89	0·87	0·92	0·92	0·88
L47	0·83	0·79	0·79	0·76	0·78	0·79	0·77
L48	0·66	0·66	0·67	0·65	0·65	0·67	0·63
L49	0·64	0·65	0·65	0·64	0·66	0·66	0·63

Operation of Instrument

The fundamental principles of the double-beam flame-photometer have been outlined above, but the instrument is manipulated as follows :—

The air manometer vernier tap is opened fully, and the main air reducing valve regulator adjusted to give more pressure on the manometer than the maximum required : the vernier tap is then closed completely. The gas supply is turned on with the vernier gas-tap fully open, and the latter closed slightly, just sufficiently to restrict full flow, thus allowing a degree of control. The burner is then lit and the vernier air tap opened and adjusted to produce a flame the cones of which reach just to the bottom edge of the lenses. The readings on the manometer are noted.

The calibration solution containing the greatest amount of lithium is then placed in a small beaker under the intake capillary of the atomiser and, with the potentiometer set at about three-quarters of its maximum scale, the potassium iris is adjusted to give zero on the galvanometer with both shutters open. (The iris is not touched again throughout the series or the calibration will be upset).

This operation presets the instrument to the range required. The shutters are then closed, the potentiometer returned to zero, and the calibration solutions read, using the potentiometer in every case to give balance. The shutters are closed between each reading and the atomiser purged with water between solutions.

Recommended Method for the Determination of Lithium in Magnesium-Lithium-Zinc Alloys

Solutions

Sulphuric Acid (20*N*)—532 ml. concentrated acid per litre.

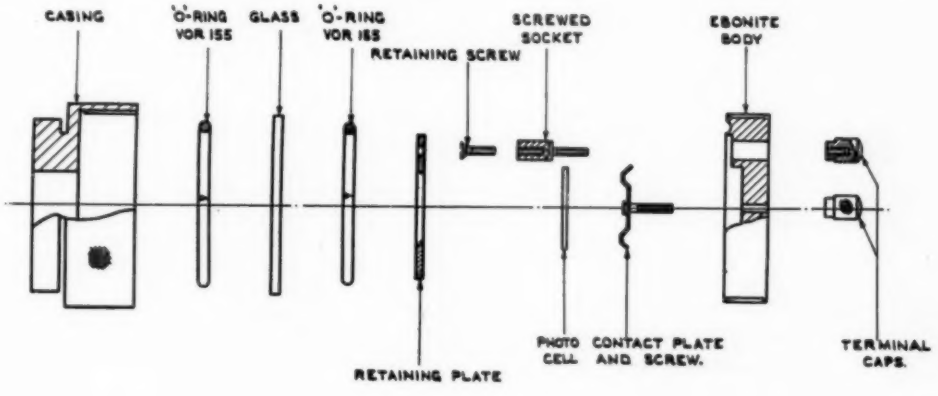


Fig. 5.—Sealed photo-cell holder. Exploded view.

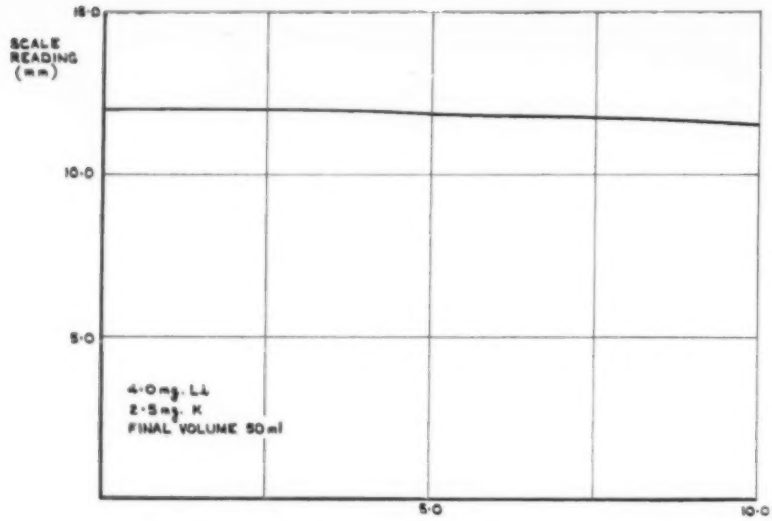


Fig. 6.—Influence of variations of acidity in the final solution.

Lithium Solution—3·688 g. lithium sulphate monohydrate per litre (5 ml. = 2 mg. lithium).

Potassium Solution—1·113 g. anhydrous potassium sulphate per litre (1 ml. = 0·5 mg. potassium).

Filters

Potassium : —1 cm. layers of each of the following
(1) 2% w/v aqueous solution of anhydrous potassium dichromate.
(2) 0·02% w/v solution of aniline blue in 95% ethanol.

Lithium :—1 cm. layers of each of the following
(1) 0·2% w/v aqueous solution of rhodamine B.
(2) 1·0% w/v solution of cupric chloride dihydrate in 8 N hydrochloric acid.

Procedure

Dissolve the sample (normally kept under benzene until required) in the appropriate quantity of 20 N sulphuric acid, calculated from the nominal composition, add an excess of 50 ml. and dilute to 1 litre. The final concentrations of sulphuric acid will then be approximately normal.

Take an aliquot to contain about 5 mg. of lithium, based on the nominal composition, transfer to a 50 ml. volumetric flask, add 5 ml. of potassium solution and dilute to the mark. The reading is taken on this solution.

Prepare six calibration solutions containing nil, 2, 4, 6, 8 and 10 mg. lithium and 5 ml. of potassium solution in each case, and dilute to 50 ml. Read these and prepare a calibration graph. In cases where the range of lithium encountered is relatively low, the calibration graph can be made from solutions containing 0–5 mg. lithium (or any other suitable range) the iris diaphragm being adjusted to give the same range on the potentiometer.

Read the unknown from the graph in terms of milligrams of lithium, and convert to percentage in the initial sample weight, making suitable correction for the aliquot taken.

Results

Some typical results, together with nominal compositions, are shown in Table II.

Conclusions

(1) The greatly increased sensitivity obtained by the use of infra-red photo-cells in a double beam flame-

TABLE II.—TYPICAL RESULTS TOGETHER WITH NOMINAL COMPOSITIONS.

Sample No.	% Nominal Composition	% Lithium found
L52	4·20	4·24
L52A	4·20	4·48
L53	3·30	3·51
L57	2·70	2·84
L63	8·20	8·66
L65	12·40	12·1
L66	10·80	10·7
L67	26·80	26·4
L68	18·80	18·4
L69	14·60	14·4
L71	23·85	23·6
L86	6·60	6·48

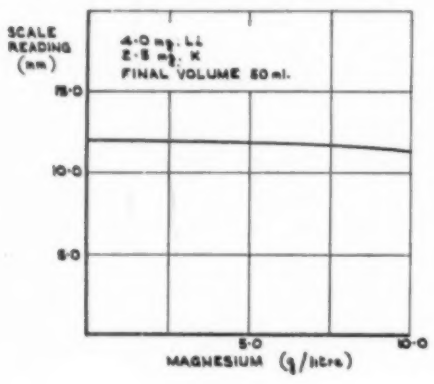
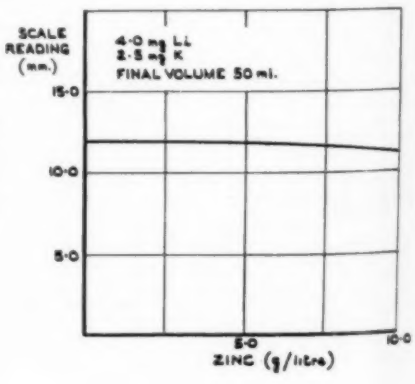


Fig. 7. (left)—Influence of magnesium concentration in the final solution.

Fig. 8. (right)—Influence of zinc concentration in the final solution.



photometer enables lithium to be determined more accurately than by conventional methods.

(2) The adverse effect of laboratory atmosphere on the cells can be overcome by the use of airtight containers.

(3) The use of a modified burner together with this enhanced sensitivity permits the use of town-gas/air instead of acetylene/air mixtures.

(4) The instrument in its final form is greatly simplified but highly versatile and accurate.

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1 Robinson and Ovenston. A Simple Flame Photometer for Internal Standard Operation and Notes on Some Liquid Spectrum Filters, *Analyst*, **76**, 416–424 (1951).

2 Domingo and Klyne. A Photoelectric Flame Photometer, *The Biochemical Journal*, **45**, 400–408 (1949).

Continuous Casting of Steel at Barrow

MILD steel billets of commercial quality are now being produced in a pilot continuous casting plant at Barrow Steel Works, Ltd., at higher casting speeds than have been attained on any other known plant of this kind. The Rossi-Junghans machine at Barrow, on which extensive development work has been carried out over the past three years, is operating at speeds in excess of 200 in./min.—the equivalent of 7 tons of 2 in. square steel billets per hour.

Carbon and alloy steels for continuous casting are melted down and refined in a 5-ton electric arc furnace. After tapping, the ladle of molten steel is teemed into a tundish at the top of the continuous casting plant, and the steel then flows at a controlled rate into a reciprocating water-cooled copper mould. A partly solidified billet—its central core is still liquid—is withdrawn from the bottom of the mould, and solidification is completed as the billet, preceded by a dummy billet, travels vertically down the machine. When it emerges in solid form, the continuously cast billet is cut to the required lengths.

The pilot plant at Barrow is capable of producing billets from 2 in. to 4 in. square and slabs of up to 6 in. by 2 in. in cross-section. Satisfactory results have been achieved in the continuous casting of mild steels, low alloy steels, and stainless steel. In subsequent manipulation, the continuously cast carbon steels have been found to have good forging characteristics, while high quality sheets have been rolled from continuously cast stainless slabs. Experiments are continuing with a view to establishing a satisfactory process which will be both economic and repetitive.

A 16-minute colour film on "Continuous Casting at Barrow" produced by the Research and Development Department of The United Steel Cos., Ltd., was shown publicly for the first time in the Sheffield Central Library during the 1956 British Association Meeting.

British Oxygen's Visual Aids to Industry

DURING the past twelve months, British Oxygen have issued industrial films showing their various processes to more than 700 technical institutes, evening classes and similar organisations. A number of short sound and silent films have been made by British Oxygen's own film unit, and other full-length documentaries have been made by independent companies. The Company's film unit was formed in 1953 as an integral part of the Sales Technical Service Department at Cricklewood, its aim being to make instructional films of the Company's various processes, in sound or sound and colour. Three films are due for completion by the end of this year, dealing with lead welding, flame cleaning and a new range of oxy-acetylene welding and cutting blowpipes. Contained within the film unit is a lantern-slide library with nearly 2,000 slides, which can be borrowed free of charge for lectures or reference purposes.

Honeywell-Brown Dublin Representative

To meet Eire's accelerating demand for instrumentation, the U.K. associates of the international Honeywell organisation now have a resident representative in Dublin. This representative, Mr. D. Tallon, can provide every assistance with the choice, installation, and maintenance of the Company's industrial instrumentation, precision snap action switches, and automatic controls for heating, ventilating and air conditioning systems. All enquiries should be addressed to Mr. D. Tallon, Resident Representative for Honeywell-Brown, Ltd., 38, Upper Mount Street, Dublin.

Change of Address

WE are advised that the address of The Institute of Welding and the General Secretariat of The International Institute of Welding is now 29 Park Crescent, London, W.1. Tel: LANgham 7488/9.

CORRESPONDENCE

AN UNUSUAL FATIGUE FAILURE

The Editor, METALLURGIA.

Sir,

The heading to the article by E. Wood in the June issue, " An Unusual Fatigue Failure," together with the photographs, attracted my attention, but before commencing to read I had put another interpretation on this failure of a hammer head.

It is sometimes unwise to judge from a photograph, but it does seem more probable to me that in this fracture zone C was the first to break as an internal clink, or transverse crack, which formed during the production or heat treatment of the hammer head ; that this clink had fatigued outwards as zone B ; and that zone A was the last to break through shear.

In the laboratories to which I am attached, we have seen several examples of this type of failure, and I enclose a photograph of the fracture of a large roll, and also that of a piston rod, both of which failed through an internal clink.

Yours faithfully,

Sheffield
August 9th, 1956

J. H. SLAGG,
English Steel Corporation, Ltd.

The Editor, METALLURGIA

Sir,

Mr. Slagg's interpretation is interesting and plausible. We too have had examples of failures in large shafts, rolls and gears, etc., in which it was impossible not to conclude that the fatigue spread outwards from an internal cavity or clink, and we are glad to receive confirmation of these failures from such an authoritative source. But in weighing this interpretation, three points need assessment :—

(1) Do clinks occur in not-too-high straight carbon steels in small sections ? Both Mr. Slagg's examples are much larger than the hammer, and in our experience the trouble is very much a feature of large sizes in alloy steels. By " clinks " internal ruptures are meant, and not ordinary heat treatment cracks. Terlecki's work (largely confirmed at English Steel Corporation) on rapid heating suggests that clinks are rare, if not unknown, in carbon steels, even in large sizes. If, in fact, clinks can occur in such steels in small sizes, then the zone C could have been so produced. But we have not met such a clink previously.

(2) It seems unlikely to us that zone A was the last to break, simply because it was discoloured much more than the other zone. Similarly the central zone was much cleaner.

(3) The microscopical evidence showed the outer zone was *certainly* burnt (or very badly overheated). Mr. Slagg passes over this fact, but the spatial coincidence of an internal clink, and the burnt zone, though not impossible, is obviously more unlikely than the random presence of either.

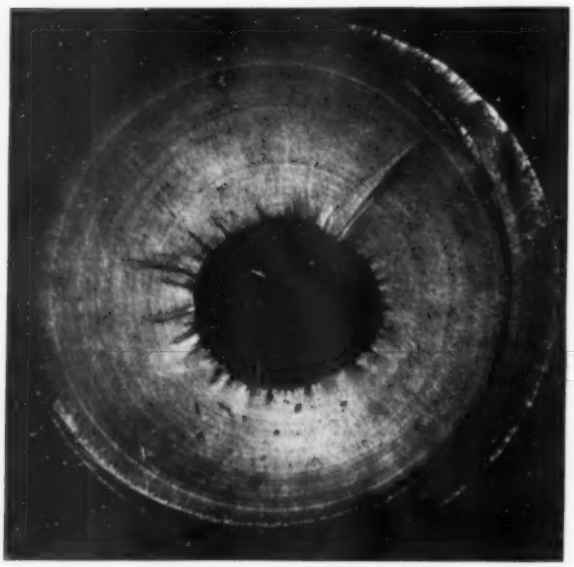
However, Mr. Slagg's interpretation is thought-provoking and the possibility of clinks in these (and similar) hand tools will be kept in mind in future. In conclusion, thanks are due to Mr. Slagg for his public spirited contribution. The failure frankly puzzled us in certain aspects, and it was precisely to elicit pooling of knowledge and experience such as this that the note was published.

Yours faithfully,

Brierley Hill, Staffs.
August 21st, 1956

E. WOOD,
Midland Research Co., Ltd.

We regret that limitations of space have delayed publication of this correspondence.—Editor.



Fractured piston rod × ½

Fractured roll × ⅓